USER MANUAL

Geo Brick Drive

Programmable Servo Amplifier

5xx-603800-xUxx

April 15, 2012

DELTA TAU
Data Systems, Inc.
NEW IDEAS IN MOTION ...

Single Source Machine Control *Power // Flexibility // Ease of Use*
21314 Lassen Street Chatsworth, CA 91311 // Tel. (818) 998-2095 Fax. (818) 998-7807 // www.deltatau.com

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Delta Tau Data Systems, Inc. Technical Support
Phone: (818) 717-5656
Fax: (818) 998-7807
Email: support@deltatau.com
Web: www.deltatau.com

Operating Conditions

All Delta Tau Data Systems, Inc. motion controller, accessory, and amplifier products contain static sensitive components that can be damaged by incorrect handling. When installing or handling Delta Tau Data Systems, Inc. products, avoid contact with highly insulated materials. Only qualified personnel should be allowed to handle this equipment.

In the case of industrial applications, we expect our products to be protected from hazardous or conductive materials and/or environments that could cause harm to the controller by damaging components or causing electrical shorts. When our products are used in an industrial environment, install them into an industrial electrical cabinet to protect them from excessive or corrosive moisture, abnormal ambient temperatures, and conductive materials. If Delta Tau Data Systems, Inc. products are directly exposed to hazardous or conductive materials and/or environments, we cannot guarantee their operation.

Safety Instructions

Qualified personnel must transport, assemble, install, and maintain this equipment. Properly qualified personnel are persons who are familiar with the transport, assembly, installation, and operation of equipment. The qualified personnel must know and observe the following standards and regulations:

IEC364resp.CENELEC HD 384 or DIN VDE 0100
IEC report 664 or DIN VDE 0110
National regulations for safety and accident prevention or VBG 4

Incorrect handling of products can result in injury and damage to persons and machinery. Strictly adhere to the installation instructions. Electrical safety is provided through a low-resistance earth connection. It is vital to ensure that all system components are connected to earth ground.

This product contains components that are sensitive to static electricity and can be damaged by incorrect handling. Avoid contact with high insulating materials (artificial fabrics, plastic film, etc.). Place the product on a conductive surface. Discharge any possible static electricity build-up by touching an unpainted, metal, grounded surface before touching the equipment.

Keep all covers and cabinet doors shut during operation. Be aware that during operation, the product has electrically charged components and hot surfaces. Control and power cables can carry a high voltage, even when the motor is not rotating. Never disconnect or connect the product while the power source is energized to avoid electric arcing.

WARNING

A Warning identifies hazards that could result in personal injury or death. It precedes the discussion of interest.

Caution

A Caution identifies hazards that could result in equipment damage. It precedes the discussion of interest.

Note

A Note identifies information critical to the user's understanding or use of the equipment. It follows the discussion of interest.

MANUAL REVISION HISTORY				
REV	**DESCRIPTION**	**DATE**	**CHANGE**	**APPROVED**
1	ANALOG INPUT SECTION	09/07/06	C.P	R.U
2	6-AXIS REGEN INFO, P. 8	03/19/07	C.P	D.G
3	PART NUMBER TABLE, P. 7	04/27/07	C.P	S.S
4	TROUBLESHOOTING CHAPTER, P. 75	09/12/07	C.P	R.N
5	TROUBLESHOOTING CHAPTER, P. 75	02/13/08	C.P	R.N
6	PART NUMBER, WIRING DIAGRAM, SETTINGS, ERROR CODES	01/27/09	C.P	S.S
7	UL LISTING	3/17/09	C.P	S. F
8	APPENDIX FOR AUXILIARY BOARD	07/23/09	C.P	S.S
9	REFURBISHED ENTIRE MANUAL, ADDED SPECIAL FEEDBACK, MACRO, MOTOR SETUP, LIST OF CHANGES, +5V ENC PWR	05/10/10	R.N	R.N
10	MANUAL REFORMATTING. CORRECTIONS AVAILABLE UPON REQUEST.	8/10/2011	R.N	R.N
11	CORRECTED Ixx71 FOR QUADRATURE LINEAR	10/10/11	R.N	R.N
12	UPDATED +5V ENC PWR SECTION	10/13/11	R.N	R.N
13	UPDATED ABSOLUTE SERIAL ENCODER SECTION. GENERAL UPDATES.	4/15/2012	R.N	R.N

Table of Contents

INTRODUCTION

The Geo Brick Drive combines the intelligence and capability of the Turbo PMAC2 motion controller with IGBT-based drive technology, resulting in a compact, smart 4-, 6- or 8-axis servo drive package.

The flexibility of the Turbo PMAC2 enables the Geo Brick to drive Brush, Brushless or AC induction motors with unsurpassed pure digital DSP performance. The absence of analog signals – required for typical motion controller/drive interfacing – enables higher gains, better overall performance and tighter integration, while significantly driving down costs and setup time.

The Geo Brick's embedded 32-axis Turbo PMAC2 motion controller is programmable for virtually any kind of motion control application. The built-in software PLCs allow for complete machine logic control.

The Geo Brick Drive supports the following types of motors:

- Three-phase AC/DC brushless, synchronous rotary/linear
- DC brush
- AC Induction, asynchronous – with or without encoder
- Stepper output to third party drives or through MACRO connectivity

Documentation

In conjunction with this user manual, the Turbo Software Reference Manual and Turbo PMAC User Manual are essential for proper use, motor setup, and configuration of the Geo Brick Drive. It is highly recommended to refer to the latest revision of the manuals found on Delta Tau's website, under Support>documentation>Manuals: Delta Tau Manuals

Downloadable Turbo PMAC Script

Caution

Some code examples require the user to input specific information pertaining to their system hardware. When user information is required, a commentary ending with **–User Input** is inserted.

This manual contains downloadable code samples in Turbo PMAC script. These examples can be copied and pasted into the editor area in the Pewin32pro2. Care must be taken when using pre-configured Turbo PMAC code, some information may need to be updated to match hardware and system specific configurations. Downloadable Turbo PMAC Scripts are enclosed in the following format:

```
// TURBO PMAC SCRIPT EXAMPLE
P1=0                                  ; Set P1=0 at download
Open PLC 1 Clear                      ; Open PLC Buffer 1, clear contents
CMDP"Geo Brick User Manual Test PLC"  ; Send unsolicited response to host port
P1=P1+1                               ; Counter using variable P1
Disable PLC 1                         ; Disable plc 1
Close                                 ; Close open buffer
```

Caution

All PLC examples are stated in PLC number 1. It is the user's responsibility to arrange their application PLCs' properly and handle power-on sequencing for various tasks.

It is the user's responsibility to use the PLC examples presented in this manual properly. That is, incorporating the statement code in the application configuration, and handling tasks in a sequential manner. For example, with serial absolute encoders, setting up the global control registers should be executed before trying to read absolute position, and absolute phase referencing. Furthermore, other PLC programs (which would be trying to move motors) should be disabled until these functions are executed.

Caution

Often times, downloadable example codes use suggested M-variables, it is the user's responsibility to make sure they are downloaded, or perform necessary changes to use the intended registers.

SPECIFICATIONS

Part Number

A B C D E F G H I

GBL 4 - C 0 - 5 0 0 - 0 0 0 0** 0** 0** 0** 0

A

Axes GBLA-BB-CDD-EFGHHHI0
4 : Four Axes Silver Enclosure
6 : Six Axes Silver Enclosure
8 : Eight Axes Silver Enclosure

B

CPU Options – GBLA-BB-CDD-EFGHHHI0
Turbo PMAC 2 Processor

C0: 80Mhz, 8Kx24 Internal, 256Kx24SRAM, 1MB Flash (Default)
C3: 80Mhz, 8Kx24 Internal, 1Mx24SRAM, 4MB Flash
F3: 240Mhz, 192Kx24 Internal, 1Mx24SRAM, 4MB Flash

C

Axes 1 to 4 Options GBLA-BB-CDD-EFGHHHI0

5: 5A/10A, with encoders and Flags for every axis (**Default**)
8: 8A/16A, with encoders and Flags for every axis
(Continuous / Peak)

D

Axes 5 to 8 Options GBLA-BB-CDD-EFGHHHI0

12-24V	5V Flags	
4 axes		
00	05	No options, 4-axis system
02	07	Four secondary encoders inputs (total of 8 encoder inputs)
P3	P8	PWM amplifier Interface for channel 7 with encoders for axes 5 to 8 (4 secondary encoders)
6 axes		
F2	F7	5 and 6 axis, 15A/30A, with encoders for channels 5 to 8 (2 secondary encoders)
W3	W8	5 and 6 axis, 15A/30A, plus PWM amplifier Interface for channel 7 with 2 secondary encoders on 7 & 8)
8 axes		
52	57	5-8 axis, 5A/10A, with encoder inputs for all axes
82	87	5-8 axis, 8A/16A, with encoder inputs for all axes

If user wants to order 5V flag inputs then he needs to specify it at the Axes 5 to 8 options
For example:
"05" No secondary encoder inputs (total of 4 encoder inputs), 5V Flag inputs
"07" Four secondary encoder inputs (total of 8 encoder inputs), 5V Flag inputs
"W8" Hi-Power 5 & 6 axes, plus PWM amplifier Interface for channels 7 (total of 8 encoder inputs) , 5V Flag inputs

*If the above **Number of Amplifier Axes** are selected then only the corresponding Axes 5 to 8 Options are available.*

E

Digital I/O Option GBLA-BB-CDD-EFGHHHI0

0: 16 IN / 8 OUT (Default)
1: Expanded digital I/O, additional 16 inputs and 8 outputs
(Total of 32 IN / 16 OUT)

Outputs are rated: 0.5A@12-24VDC

F

Analog I/O Options GBLA-BB-CDD-EFGHHHI0

4 axes 00 / 05 02 / 07
- **0**: No options (Default)
- **2:** Four GPIO Relays (On connectors X9-X12)
- **3**: Two Analog In, two analog Out (On conn. X11-X12) & 4 GPIO Relays (On connectors X9-X12)
- **4**: Four Analog In, four analog Out (On conn. X9-X12) & 4 GPIO Relays (On connectors X9-X12)
- **5**: Two Analog In, two analog Out (On conn. X11-X12) & 2 AENA Relays for Chan. 3&4 (On conn. X11-X12) and 2 GPIO Relays (On conn. X9-X10)
- **6**: Four Analog In, four analog Out (Connectors X9-X12) with 2 AENA Relays for Chan. 3&4 (On conn. X11-X12) and 2 GPIO Relays (On conn. X9-X10)
- **9**: Two AENA Relays for Chan.3&4 (Conn.X11-X12) and 2 GPIO Relays (On conn.X9-X10)

4 axes P3 / P8
- **0**: No options (Default)
- **2:** Four GPIO Relays (On connectors X9-X12)
- **7**: Two Analog In, 2 analog Out (Conn.X9-X10) & 4 GPIO Relays (On connectors X9-X12)
- **8**: Two Analog In, 2 analog Out (Conn.X9-X10) & 2 AENA Relays for Chan. 3&4 (On conn. X11-X12) and 2 GPIO Relays (On connectors X9-X10)
- **9**: Two AENA Relays for Chan.3&4 (Conn.X11-X12) and 2 GPIO Relays (On conn.X9-X10)

6 axes F2 / F7
- **0:** No options (Default)
- **2:** Four GPIO Relays (On connectors X9-X12)
- **3:** Two Analog In, two analog Out (On conn. X11-X12) & 4 GPIO Relays (On connectors X9-X12)
- **5**: Two Analog In, two analog Out (On conn. X11-X12) & 4 AENA Relays for Chan.3&4 (On conn.X11-X12) and Chan.5&6 (On conn.X9-X10)
- **9**: Four AENA Relays for Chan.3&4 (On conn.X11-X12) and Chan.5&6 (On conn.X9-X10)

6 axes W3 / W8, 8 axes 52 / 57 82 / 87
- **0**: No Analog Options available, for this configurations
  To receive Analog Inputs for these configurations, you must order GBLA-BB-CDD-EFGHHHI0 ***MUXED ADC Option in "MACRO and Special Feedback Options"***
- **2:** Four GPIO Relays (On connectors X9-X12)
- **9**: Four AENA Relays for Chan.3&4 (On conn.X11-X12) and Chan.5&6 (On conn.X9-X10)

Note: Analog outputs are 12-bit filtered PWM and Analog Inputs are 16-bit.

G

Communication Options GBLA-BB-CDD-EFGHHHI0

USB2 and Eth100 are included
Note: To use PMAC-NC software, DPRAM is required

0xxxxx: No Options, Default
Dxxxxx: DPRAM option, size 8K x 16-bit wide
Mxxxxx: ModBus Ethernet Communication Protocol (Software) option
Sxxxxx: DPRAM and Modbus Options Combined

R00000: RS232 port on 9-pin D-sub Connector*
E00000: DPRAM & RS232 Options Combined*
N00000: RS232 & ModBus Options Combined*
T00000: Modbus, DPRAM & RS232 Combined*

**** If any of the "H" or "I" digits is non zero (GBLA-BB-CDD-EFGHHHI0) then RS232 is included as default. Options R, E, N and T are Incompatible***

MACRO and Special Feedback Options

I

MACRO Ring Interface and 8 Single or 4 Differential channel 12-bit 10v range MUXED ADC

GBLA-BB-CDD-EFGHHHI0
0: No MACRO or ADC
1: RJ45 MACRO
2: Fiber Optic MACRO
3: MUXED ADC
4: RJ45 MACRO and MUXED ADC
5: Fiber Optic MACRO and MUXED ADC

H

Special Feedback Number and Type of Channels

GBLA-BB-CDD-EFGHHHI0
000: No Special Feedback Channels
4A0: 4 Sinusoidal Encoder Feedback Channels
4B0: 4 Resolver Feedback Channels
4C1: 4 Serial Encoder Feedback Channels ***(SSI Protocol)***
4C2: 4 Serial Encoder Feedback Channels ***(Yaskawa Sigma II Protocol)***
4C3: 4 Serial Encoder Feedback Channels ***(EnDat Protocol)***
4C5: 4 Serial Encoder Feedback Channels ***(Tamagawa Protocol)***
4D1: 4 Sinusoidal Encoder and Serial Enc. ***(SSI Protocol)***
4D2: 4 Sinusoidal Encoder and Serial Enc. ***(Yaskawa Sigma II Protocol)***
4D3: 4 Sinusoidal Encoder and Serial Enc. ***(EnDat Protocol)***
4D4: 4 Sinusoidal Encoder and Serial Enc. ***(HiperFace Protocol)***
4D5: 4 Sinusoidal Encoder and Serial Enc. ***(Tamagawa Protocol)***
4E1: 4 Resolver Feedback Channels and Serial Enc. ***(SSI Protocol)***
4E2: 4 Resolver Feedback Ch. and Serial Enc. ***(Yaskawa Sigma II Protocol)***
4E3: 4 Resolver Feedback Channels and Serial Enc. ***(EnDat Protocol)***
4E5: 4 Resolver Feedback Channels and Serial Enc. ***(Tamagawa Protocol)***
8A0: 8 Sinusoidal Encoder Feedback Channels
8B0: 8 Resolver Feedback Channels
8C1: 8 Serial Encoder Feedback Channels ***(SSI Protocol)***
8C2: 8 Serial Encoder Feedback Channels ***(Yaskawa Sigma II Protocol)***
8C3: 8 Serial Encoder Feedback Channels ***(EnDat Protocol)***
8C5: 8 Serial Encoder Feedback Channels ***(Tamagawa Protocol)***
8D1: 8 Sinusoidal Encoder and Serial Enc. ***(SSI Protocol)***
8D2: 8 Sinusoidal Encoder and Serial Enc. ***(Yaskawa Sigma II Protocol)***
8D3: 8 Sinusoidal Encoder and Serial Enc. ***(EnDat Protocol)***
8D4: 8 Sinusoidal Encoder and Serial Enc. ***(HiperFace Protocol)***
8D5: 8 Sinusoidal Encoder and Serial Enc. ***(Tamagawa Protocol)***
8E1: 8 Resolver Feedback Channels and Serial Enc. ***(SSI Protocol)***
8E2: 8 Resolver Feedback Ch. and Serial Enc. ***(Yaskawa Sigma II Protocol)***
8E3: 8 Resolver Feedback Channels and Serial Enc. ***(EnDat Protocol)***
8E5: 8 Resolver Feedback Channels and Serial Enc. ***(Tamagawa Protocol)***

Note: If any of the "H" or "I" digits (GBLA-BB-CDD-EFGHHHI0) are ordered, you will also receive RS-232 comms port, 2 channel "handwheel" port.

Geo Brick Drive Options

CPU Options

- C0: 80MHz Turbo PMAC2 CPU (Standard, default)
  8Kx24 internal memory, 256Kx24 SRAM, 1MB flash memory
- C3: 80MHz Turbo PMAC2 CPU
  8Kx24 internal memory, 1Mx24 SRAM, 4MB flash memory
- F3: 240MHz Turbo PMAC2 CPU
  192Kx24 internal memory, 1Mx24 SRAM, 4MB flash memory

Encoder Feedback

- Digital Quadrature
- Sinusoidal
- HiperFace
- Resolver
- SSI
- EnDat 2.1 / 2.2
- Yaskawa Sigma II / III
- BiSS B / C
- Panasonic
- Tamagawa

Note

Regardless of the encoder feedback option(s) fitted, digital quadrature encoders can always be utilized. However, Hall sensors cannot be used with a channel which has been programmed for serial clocking.

Axes Power Configuration

- 5/10 Amps or 8/16 Amps, 15/30 Amps (limited to axis 5-6)

Encoder Inputs

- Up to eight encoder inputs, one handwheel quadrature input
- Additional encoder inputs can be obtained through MACRO connectivity

Digital Inputs/Outputs

- Up to 32 inputs and 16 outputs (Sinking or Sourcing)
- Additional digital I/Os can be obtained through Fieldbus connectivity

Analog Inputs, DAC Outputs, Brakes, and Relays

- Up to four 16-bit analog inputs, eight 12-bit analog inputs, four brake/ relay outputs , and five 12-bit filtered PWM (±10V) outputs

Communication

- USB 2.0, Ethernet 100 Base T, RS232, DPRAM (required for NC software/applications)

Fieldbus Connectivity

- MACRO
- ModBus

Environmental Specifications

Description	Specifications
Operating Temperature	0 to 45°C Above 40°C,de-rate current output by 2.5% per °C
Storage Temperature	-25°C to +70°C
Humidity	10% to 90% non-condensing
Operating Altitude	~3300 Feet (1000 m) De-rate current output by 1.1% per additional 330 feet (100m)
Air Flow Clearances	~3 inches (76.2mm) above and below unit for air flow
Operating Environment	Pollution Degree 2 or equivalent

Protection Specifications

Caution

The internal I^{2}T applies to and protects the amplifier power blocks. The software I^{2}T (described in later section) has to be configured properly to protect against motor/equipment damage.

Description	Specifications
Over Voltage	~ 283 VAC / 400 VDC
Under Voltage	~ 87 VAC / 123 VDC
Over Temperature	~ 80°C
Motor Short Circuit	500 % of rated peak Amps per axis
Over Current	110 % over rated peak Amps per axis
AC Input Phase Loss Detection	Loss of one or more phases (3 Phase operation only)
Shunt Fault Detection	Integrated, I^{2}T model
Internal I^{2}T protection	2 seconds at peak rated Amps (RMS) per axis

Note

The under voltage fault triggers when the AC Input dips below 87 VAC. However, if this threshold has not been reached (i.e. Low Voltage/DC operation) the under voltage logic remains unarmed.

Agency Approvals

Description	Specifications
UL	UL508C File E307874
cUL	CSA C22.2 No. 14-05 File E307874

Electrical Specifications

4-Axis Geo Brick Drive

	GBL4-xx-5xx-xxx xxxxx	GBL4-xx-8xx-xxx xxxxx
Output Continuous Current (rms/axis)	5A	8A
Output Peak Current for 2 seconds (rms/axis)	10A	16A
Rated Input Current @240VAC 3-phase(all axes)	13A	21A
Max ADC (I^2T Settings)	16.26A	26.02A
Output Power Per Axis [Watts] (Modulation depth of 60% RMS)	1247W	1995W
Output Power Total [Watts]	4988W	7980W
Power Dissipation [Watts]	498W	798W
PWM Frequency Operating Range [KHz]	1 – 18	
AC Input Line Voltage [VAC rms]	$110^{-20\%}$ – $240^{+10\%}$ (~87 -- 264)	
DC Input Line Voltage [VDC]- DC operation	12VDC to 340VDC	
Logic Power [VDC, A]	24VDC, 2A	
Continuous Shunt Power rating [Watts]	5000W	
Peak Shunt Power rating [Watts]	10000W	
Recommended Shunt Resistor [Ohms]	GAR15 (15Ω)	
Recommended Shunt Power Rating [Watts]	300W	

6-Axis Geo Brick Drive

	GBL6-xx-5xx-xxx xxxxx		GBL6-xx-8xx-xxx xxxxx	
Axes	**1-4**	**5-6**	**1-4**	**5-6**
Output Continuous Current (rms/axis)	5A	15A	8A	15A
Output Peak Current for 2 seconds (rms/axis)	10A	30A	16A	30A
Max ADC (I^2T Settings)	16.26A	48.8A	26.02A	48.8A
Rated Input Current @240VAC 3-phase(all axes)	33A		41A	
Output Power Per Axis (Modulation depth of 60% RMS)	1247 W	3741 W	1995	3741
Output Power Total	12470W		15462W	
Power Dissipation [Watts]	1247W		1546W	
PWM Frequency Operating Range [KHz]	1 – 18			
AC Input Line Voltage [VAC rms]	$110^{-20\%}$ – $240^{+10\%}$ (~87 -- 264)			
DC Input Line Voltage [VDC]- DC operation	12VDC to 340VDC			
Logic Power [VDC, A]	24VDC, 3A			
Continuous Shunt Power rating [Watts]	7500W			
Peak Shunt Power rating [Watts]	15000W			
Recommended Shunt Resistor [Ohms]	GAR 10 (10 Ω)			
Recommended Shunt Power Rating [Watts]	300W			

8-Axis Geo Brick Drive	GBL8-xx-552		GBL8-xx-882		GBL8-xx-582		GBL8-xx-852	
Axes	**1-4**	**5-8**	**1-4**	**5-8**	**1-4**	**5-8**	**1-4**	**5-8**
Output Continuous Current (rms/axis)	5A	5A	8A	8A	5A	8A	8A	5A
Output Peak Current for 2 sec (rms/axis)	10A	10A	16A	16A	10A	16A	16A	10A
Max ADC (I^2T Settings)	16.26A	16.26A	26.02A	26.02A	16.02A	26.02A	26.02A	16.02A
Rated Input Current @240 3-phase(all axes)	26A		42A		34A		34A	
Output Power Per Axis (Modulation depth 60% RMS)	1247W		1995W		1247W	1995W	1995W	1247W
Output Power Total	9976W		15960W		12968W		12968W	
Power Dissipation	998W		1596W		1297W		1297W	
PWM Frequency Operating Range [KHz]	1 – 18							
AC Input Line Voltage [VAC]	$110^{-20\%}$ – $240^{+10\%}$ (~87 -- 264)							
DC Input Line Voltage [VDC]- DC operation	12VDC to 340VDC							
Logic Power	24VDC, 4A							
Continuous Shunt Power [Watts]	5000W							
Peak Shunt Power rating [Watts]	10000W							
Recommended Shunt Resistor [Ohms]	GAR 15 (15 Ω)							
Recommended Shunt Power Rating [Watts]	300W							

Note

Electrical specifications are specified for three-phase AC bus power. De-rating applies in single-phase AC, or DC Operation.

Receiving and Unpacking

Delta Tau products are thoroughly tested at the factory and carefully packaged for shipment. When the Geo Brick Drive is received, there are several things to be done immediately:

- Observe the condition of the shipping container and report any damage immediately to the commercial carrier that delivered the drive.
- Remove the drive from the shipping container and remove all packing materials. Check all shipping material for connector kits, documentation, or other small pieces of equipment. Be aware that some connector kits and other equipment pieces may be quite small and can be accidentally discarded if care is not used when unpacking the equipment. The container and packing materials may be retained for future shipment.
- Verify that the part number of the drive received is the same as the part number listed on the purchase order.
- Inspect the drive for external physical damage that may have been sustained during shipment and report any damage immediately to the commercial carrier that delivered the drive.
- Electronic components in this product are design-hardened to reduce static sensitivity. However, use proper procedures when handling the equipment.
- If the Geo Brick Drive is to be stored for several weeks before use, be sure that it is stored in a location that conforms to published storage humidity and temperature specifications.

Use of Equipment

The following restrictions will ensure the proper use of the Geo Brick Drive:

- The components built into electrical equipment or machines can be used only as integral components of such equipment.
- The Geo Brick Drive must not be operated on power supply networks without a ground or with an asymmetrical ground.
- If the Geo Brick Drive is used in residential areas, or in business or commercial premises, implement additional filtering measures.
- The Geo Brick Drive may be operated only in a closed switchgear cabinet, taking into account the ambient conditions defined in the environmental specifications.

Delta Tau guarantees the conformance of the Geo Brick Drives with the standards for industrial areas stated in this manual, only if Delta Tau components (cables, controllers, etc.) are used.

Mounting

The location of the Geo Brick Drive is important. Installation should be in an area that is protected from direct sunlight, corrosives, harmful gases or liquids, dust, metallic particles, and other contaminants. Exposure to these can reduce the operating life and degrade performance of the drive.

Several other factors should be carefully evaluated when selecting a location for installation:

- For effective cooling and maintenance, the Geo Brick Drive should be mounted on a smooth, non- flammable vertical surface.
- At least 76 mm (3 inches) top and bottom clearance must be provided for air flow. At least 10 mm (0.4 inches) clearance is required between units (each side).
- Temperature, humidity and Vibration specifications should also be taken in account.

Caution

Unit must be installed in an enclosure that meets the environmental IP rating of the end product (ventilation or cooling may be necessary to prevent enclosure ambient from exceeding 45° C [113° F]).

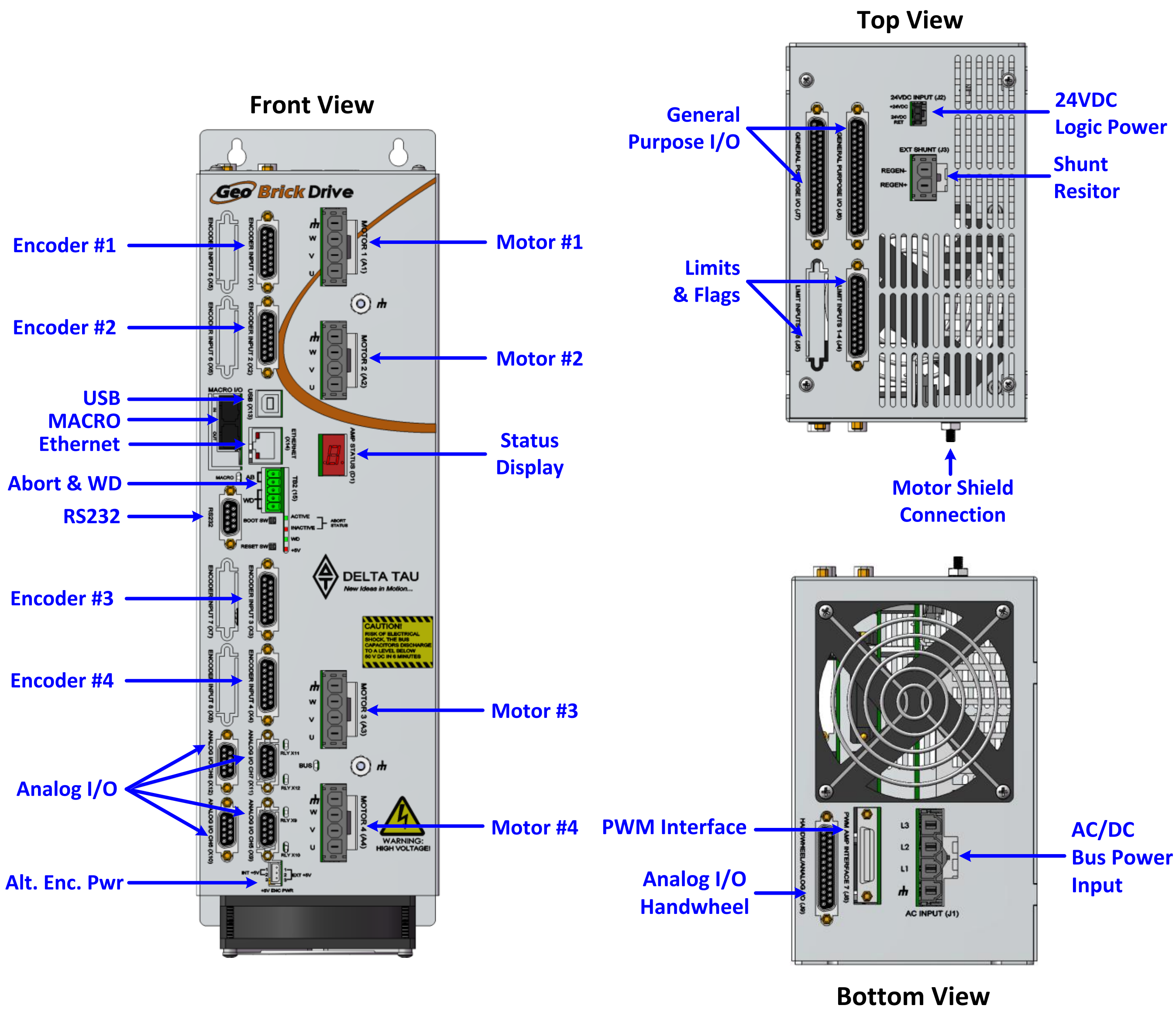
The Geo Brick Drive can be mounted with a traditional 4-hole panel mount, two U shape/notches on the bottom and two pear shaped holes on top.

If multiple Geo Brick Drives are used, they can be mounted side-by-side, leaving at least a 122 mm clearance between drives. This means a 122 mm center-to-center distance (0.4 inches) with the 4-axis Drives. 8- and 6-axis Geo Brick Drives can be mounted side by side at 214 mm center-to-center distance (8.4 inches). It is extremely important that the airflow is not obstructed by the placement of conduit tracks or other devices in the enclosure.

If the drive is mounted to a back panel, the back panel should be unpainted and electrically conductive to allow for reduced electrical noise interference. The back panel should be machined to accept the mounting bolt pattern of the drive.

The Geo Brick Drive can be mounted to the back panel using four M4 screws and internal-tooth lock washers. It is important that the teeth break through any anodization on the drive's mounting gears to provide a good electrically conductive path in as many places as possible. Mount the drive on the back panel so there is airflow at both the top and bottom areas of the drive (at least three inches).

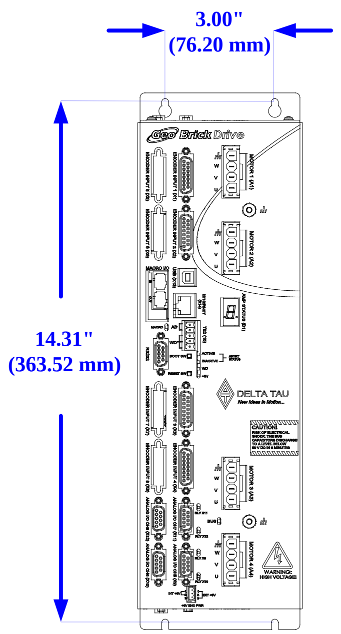
Connector Locations

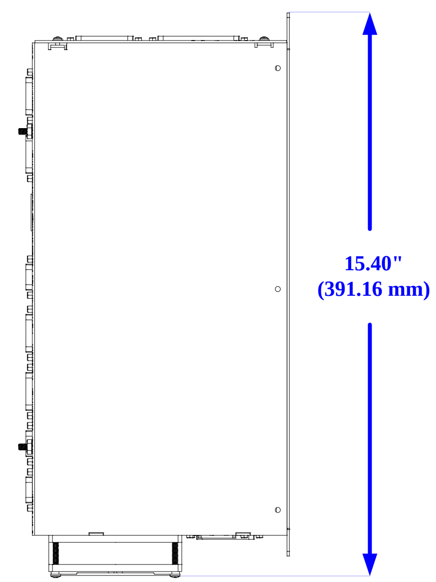


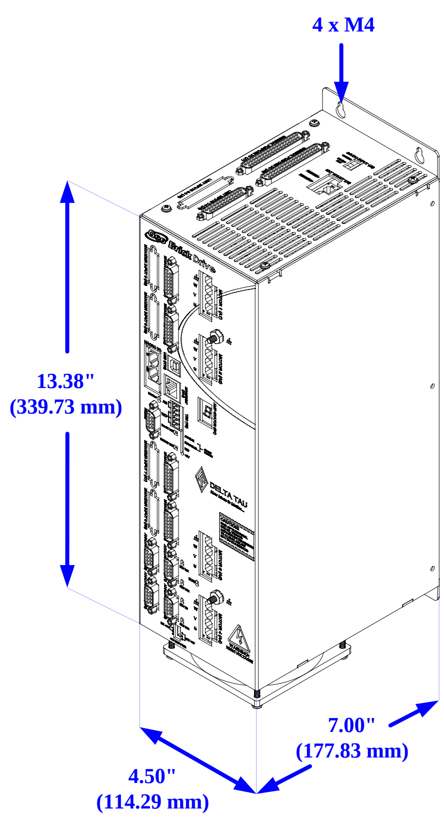
4-Axis Geo Brick Drive

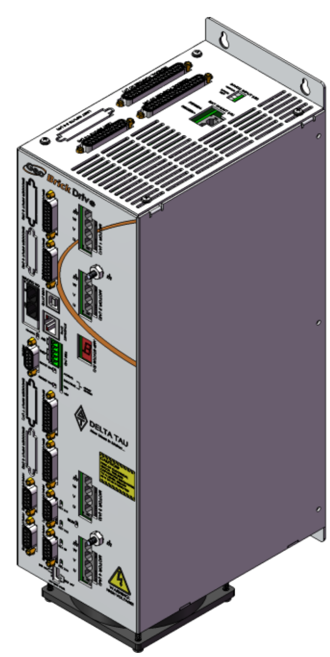
GBL4-xx-5xx-xxx-xxxx And **GBL4-xx-8xx-xxx-xxxx**

Width	Depth	Height	Weight
114mm/4.50in	178mm/7.00in	391mm/15.40in	4.4Kg/9.6lbs





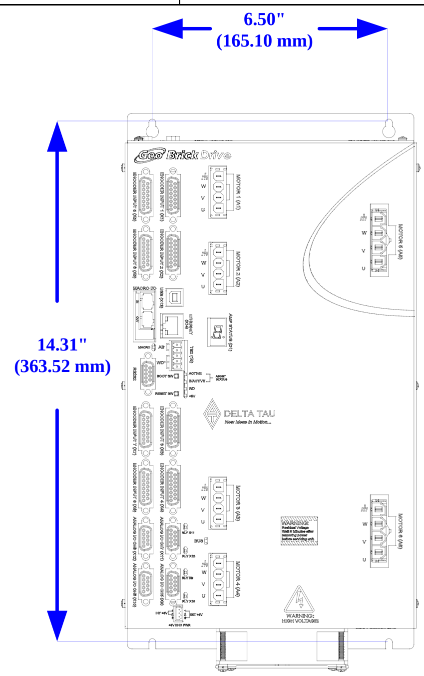


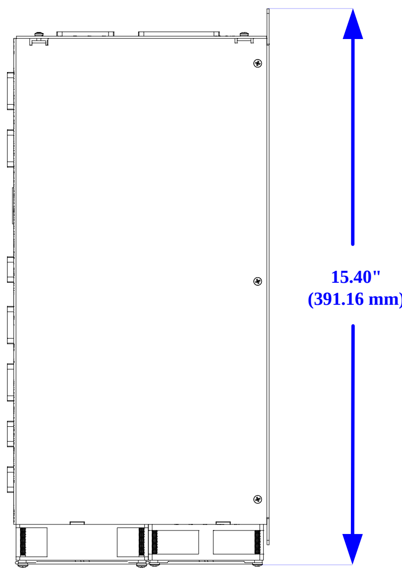


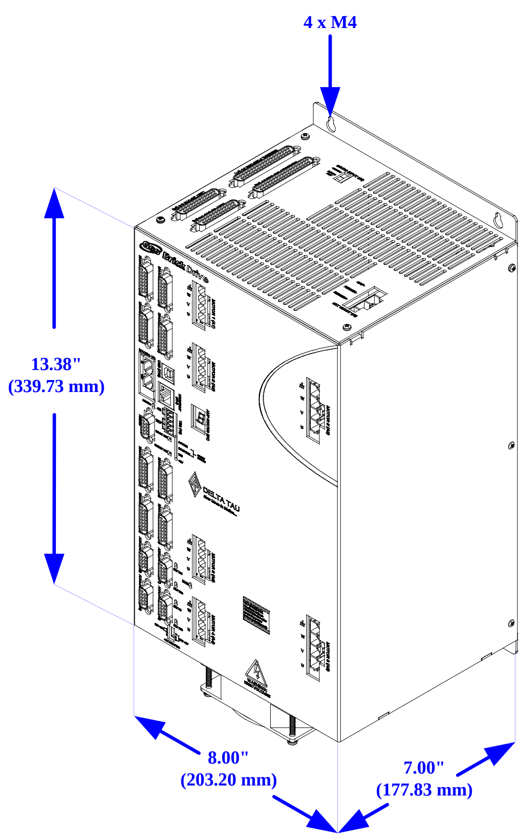
6-Axis Geo Brick Drive

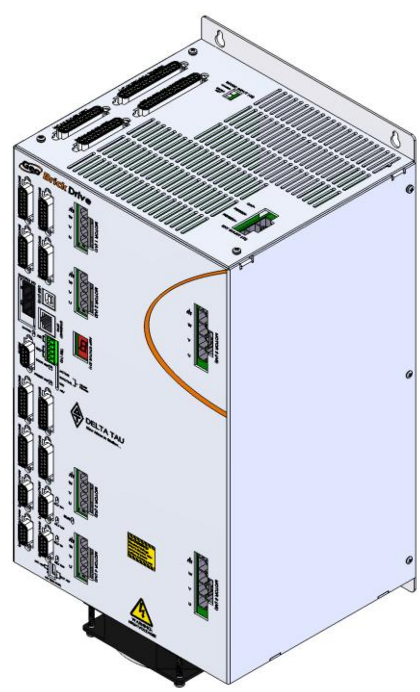
GBL6-xx-5xx-xxx-xxxx And **GBL6-xx-8xx-xxx-xxxx**

Width	Depth	Height	Weight
203mm/8.00in	178mm/7.00in	391mm/15.40in	





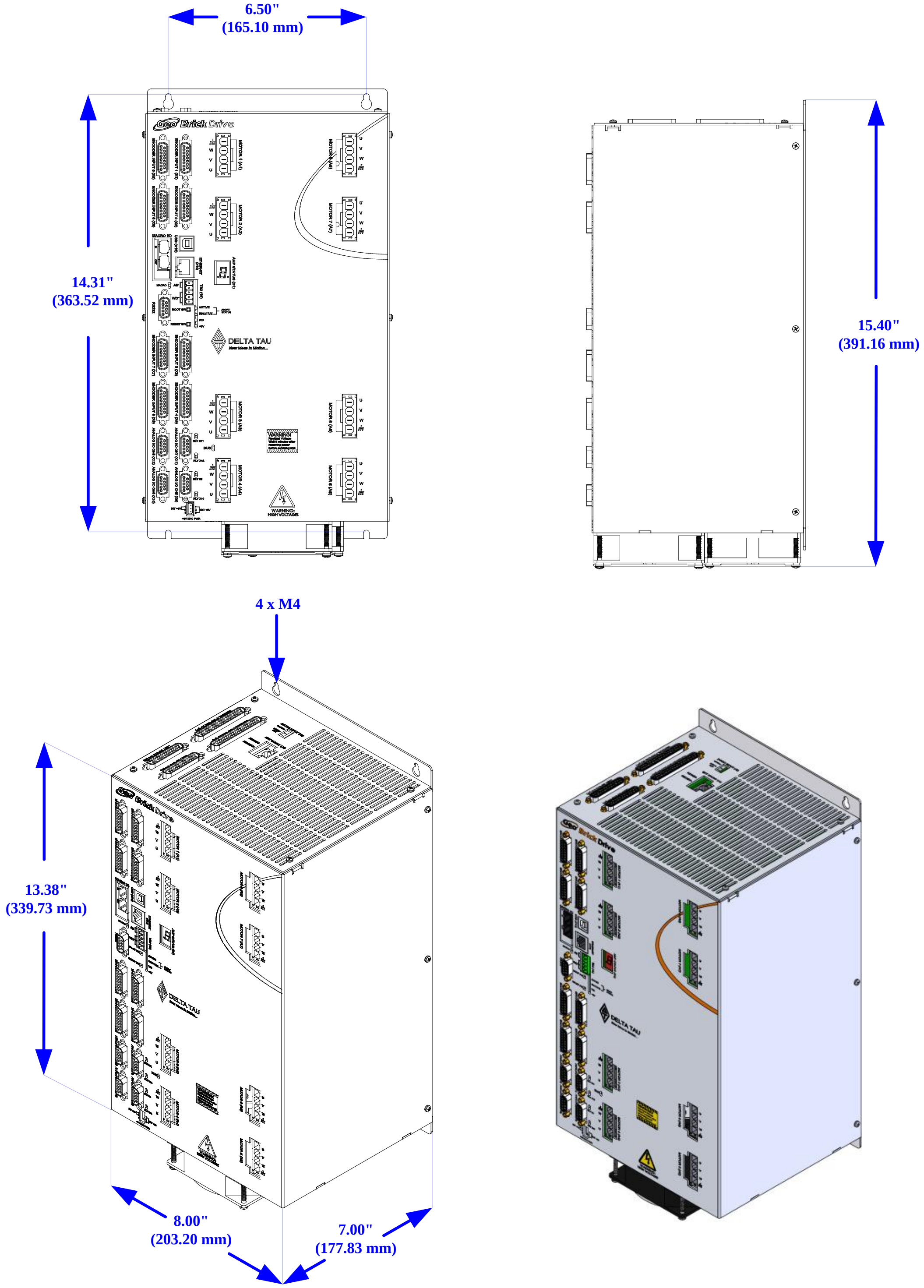




8-Axis Geo Brick Drive

GBL8-xx-552-xxx-xxxx, GBL8-xx-582-xxx-xxxx, GBL8-xx-852-xxx-xxxx, GBL8-xx-882-xxx-xxxx

Width	Depth	Height	Weight
203mm/8.00in	178mm/7.00in	392mm/15.40in	9.0 Kg/19.9lbs



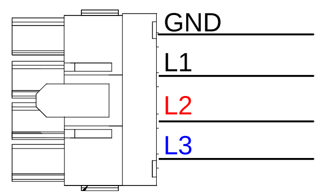
CONNECTIONS AND SOFTWARE SETUP

WARNING

Installation of electrical equipment is subject to many regulations including national, state, local, and industry guidelines and rules. The following are general recommendations but it is important that the integration be carried out in accordance with all regulations pertaining to the installation.

J1: AC/DC Bus Power Input

J1 is used to bring the AC/DC bus power into the Geo Brick Drive.

<table>
<tr><td colspan="3">J1: Molex 4-pin Male
Mating: Molex 4-pin Female</td><td colspan="3">
</td></tr>
<tr><th>Pin #</th><th>Symbol</th><th>Function</th><th>Three Phase</th><th>Single Phase</th><th>DC</th></tr>
<tr><td>1</td><td>GND</td><td colspan="4">Ground</td></tr>
<tr><td>2</td><td>L1</td><td>Input</td><td>AC Line Phase 1</td><td>Not Connected</td><td>Not Connected</td></tr>
<tr><td>3</td><td>L2</td><td>Input</td><td>AC Line Phase 2</td><td>Neutral</td><td>DC- Return</td></tr>
<tr><td>4</td><td>L3</td><td>Input</td><td>AC Line Phase 3</td><td>Line</td><td>DC+</td></tr>
</table>

Molex Mating Connector p/n: 0428160412
Molex Pins p/n : 0428150031
Molex Crimper Tool p/n: 63811-1500

Delta Tau Mating Connector p/n: 014-H00F04-049 (for internal use)
Delta Tau Pins p/n: 014-042815-031 (for internal use)

Note

In single phase operation, use L2 and L3, and leave L1 floating.
In DC mode operation, use L3 for DC+ and L2 for DC return, and leave L1 floating.

Recommended Bus Input Wiring/Protection

Caution

Main bus power lines should run in a separate duct (at least 12" or 30 cm away) from and should never be bundled with the I/O signal, communication, and encoder cables.

Caution

Current models of the 6-axis Geo Brick Drives require a delay of at least 6 minutes between main bus power cycles. This allows discharging the capacitors' residual power.

In some applications, this delay may not desirable. Contact Delta Tau directly to learn about using the shunt resistor as a bleeding resistor, thus avoiding the downtime delay.

Caution

With the current 4- and 8- axis Geo Brick Drive models, avoid recycling the main bus power ON and OFF frequently and rapidly within a few seconds.

Note

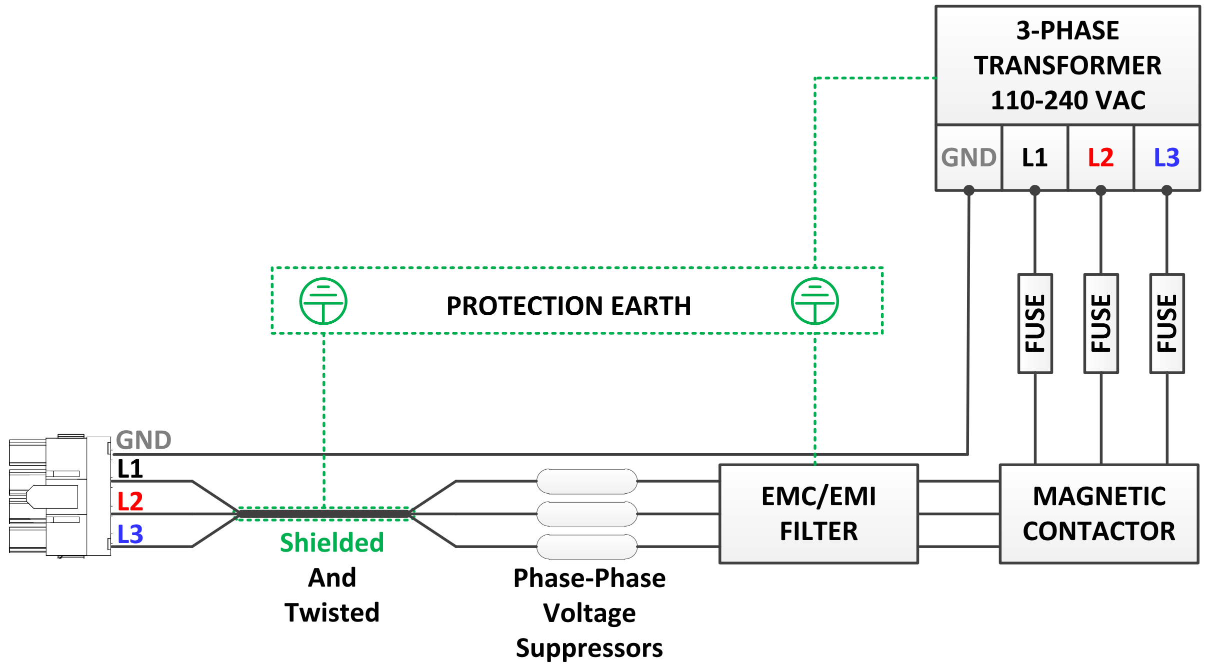
The next revision (mid 2012) of Geo Brick Drives, all models, does NOT require delays, or have restrictions on recycling main bus power. It utilizes an internal bleeding resistor to drain the excess power; subsequently turning the bus LED indicator off instantaneously when the main bus power is disconnected.

Grounding, Bonding

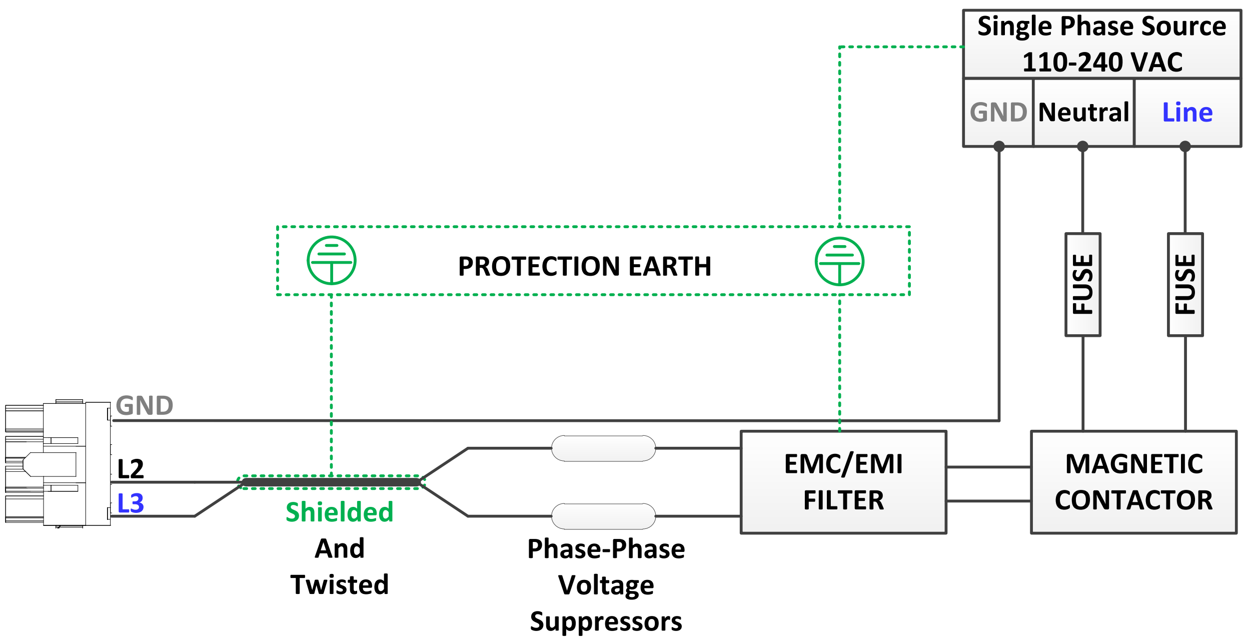
System grounding is crucial for proper performance of the Geo Brick Drive. Panel wiring requires that a central earth-ground (also known as ground bus bar) location be installed at one part of the panel. The ground bus bar is usually a copper plate directly bonded to the back panel. This electrical ground connection allows for each device within the enclosure to have a separate wire brought back to the central earth-ground.

- Implement a star point ground connection scheme; so that each device wired to earth ground has its own conductor brought directly back to the central earth ground plate (bus bar).
- Use an unpainted back panel. This allows a wide area of contact for all metallic surfaces, reducing frequency impedances.
- Use a heavy gauge ground earth conductors made up of many strands of fine conducts.
- The Geo Brick Drive is brought to the earth-ground via one or two wire(s) connected to the M4 mounting stud(s) through a heavy gauge multi-strand conductor to the central earth-ground.

Three-Phase AC Wiring Diagram



Single-Phase AC Wiring Diagram



Transformers

Y-Y or Y-Δ transformers should be used.

Δ-Δ Transformers are NOT advised. They try to balance phases dynamically, creating instances of instability in the Geo Brick Drive's rectifying circuitry.

Note

A line reactor should be installed if a transformer or reliable source of power is not available. Line reactors suppress harmonics bi-directionally, eliminating low frequency spikes.

Fuses

High peak currents and high inrush currents demand the use of slow blow time delayed type fuses. RK1 or RK5 (i.e. current limiting) classes are recommended. **FRN-R** and **LPN-RK** from **Cooper Bussmann** or similar fuses can be used.

The following table summarizes fuse gauges for three-phase bus input (240VAC) at full load:

Model	Fuse (amps)
GBL**4**-xx-**5**xx	15
GBL**4**-xx-**8**xx	25
GBL**6**-xx-**5**xx	35
GBL**6**-xx-**8**xx	45

Model	Fuse (amps)
GBL**8**-xx-**552**	30
GBL**8**-xx-**882**	45
GBL**8**-xx-**582**	35
GBL**8**-xx-**852**	35

Specific applications fuse sizing can be done using the following equations.
Take, as an example, a 4-axis Geo Brick (5/10A) on 240VAC bus, and driving 4 motors (5A continuous current rating):

DC Bus Voltage:	$V_{DCBus} = \sqrt{2} \times V_{ACBus} = 1.414 \times 240 = 339.4$	[VDC]
Motor Phase voltage:	$V_{MotorPhase} = \frac{V_{DCBus}}{\sqrt{6}} = \frac{339}{2.45} = 138.5$	[VDC]
Power per axis:	$P_{Axis} = 3 \times V_{MotorPhase} \times I_{MotorPhase} \times 0.6 = 3 \times 138.6 \times 5 \times 0.6 = 1247$	[Watts]
Total power:	$P_{Total} = \sum P_{Axis} = 4 \times 1247 = 4988.3 \text{ Watts}$	[Watts]
Dissipated power:	$P_{Dis} = 0.1 \times P_{Total} = 0.1 \times 4988 = 498.8 \text{ Watts}$	[Watts]
Current draw per phase (for 3Φ bus input)	$I_{3Phase} = \frac{P_{Total} + P_{Dis}}{\sqrt{3} \times V_{ACBus}} = \frac{4988 + 499}{1.732 \times 240} = 13.2 \text{ Amps}$	[Amps]
Current draw per phase (for 1Φ bus input)	$I_{1Phase} = \frac{P_{Total} + P_{Dis}}{\sqrt{3} \times V_{ACBus}} = \frac{4988 + 499}{1.732 \times 240} = 22.8 \text{ Amps}$	[Amps]

Thus, 15 and 25 –amp fuses are chosen for three and single phase bus power input lines respectively.

Magnetic Contactors

SC-E series from **Fuji Electric** or similar contactor can be used.

Line Filters

Line filters eliminate electromagnetic noise in a bi-directional manner (from and into the system).
T type filters are NOT recommended. PI type line filters are highly advised:

- Filter should be mounted on the same panel as the drive and power source.
- Filter should be mounted as close as possible to the power source.
- Filter should be mounted as close as possible to incoming cabinet power.

FN-258 series from **Schaffner** or similar filter can be used.

Voltage Suppressors

Voltage suppressors eliminate undesirable voltage spikes typically generated by the magnetic contactor or external machinery in the plant.
This 3-phase **voltage arrester** from **Phoenix Contact** or similar suppressor can be used.

Bus Power Cables

The Geo Brick Drive electronics create a DC bus by rectifying the incoming AC lines. The current flow into the drive is not sinusoidal but rather a series of narrow, high-peak pulses. Keeping the incoming impedance small is essential for not hindering these current pulses.
Whether single- or three-phase, it is important that the AC input wires be twisted together to eliminate noise radiation as much as possible. Recommended wire gauge:

Model	Wire Gauge (AWG)
GBL4-xx-5xx	12
GBL4-xx-8xx	10
GBL6-xx-5xx	8
GBL6-xx-8xx	8

Model	Wire Gauge (AWG)
GBL8-xx-552	10
GBL8-xx-882	8
GBL8-xx-582	8
GBL8-xx-852	8

Note

All ground conductors should be 8AWG minimum using wires constructed of many strands of small gauge wire. This ensures the lowest impedance to high-frequency noises.

J2: 24VDC Logic Power Input

J2 is used to bring the 24VDC logic power into the Geo Brick Drive. This power can remain on, regardless of the main AC/DC bus power input, allowing the digital control electronics to be active while the main motor power control is passive.

It is recommended to use a protected power supply. In situations where the power supply is shared with other devices, it may be desirable to insert a filter before applying it to the Geo Brick Drive.

If multiple drives are driven out of the same 24VDC power supply, it is recommended that each Geo Brick Drive be wired back to the power supply terminals independently. It is also recommended that the power supply be sized to handle the instantaneous inrush current required to start up the DC-to-DC converter action inside the Drive(s). See electrical specifications.

J2: Molex 2-pin Female **Mating: Molex 2-pin Male**				
Pin #	**Symbol**	**Function**	**Description**	**Notes**
1	24VDC RET	Common	Control power return	Control power return
2	+24VDC	Input	Control power input	24VDC +/-10%

Molex Mating Connector p/n: 0436450200
Molex Pins p/n: 0430300008
Molex Crimper Tool p/n: 11-01-0185

Delta Tau Mating Connector p/n: 014-043645-200 (for internal use)
Delta Tau pins p/n: 014-043030-008 (for internal use)

Recommended Wire Gauge

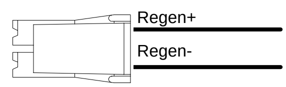
This connection can be made using a 22 AWG wire.

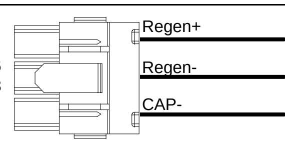
J3: External Shunt Resistor

J3 is used to wire an external shunt resistor to expel the excess power during demanding deceleration profiles. The GAR10 and GAR15 resistors are designed to drain excess bus energy very quickly. The 4- and 8-axis Geo Brick Drives are designed for operation with external shunt resistors of 15 Ohms, 6-axis units requiring 10 Ohms. Delta Tau provides these resistors with pre-terminated cables that plug directly into connector J3.

Caution

All applications using Geo Brick Drives (all configurations) are strongly advised to install an external shunt resistor.

4-, And 8-Axis Geo Brick		
J3: Molex 2-pin Female **Mating: Molex 2-pin Male**		GBL4 
Pin #	**Symbol**	**Function**
1	REGEN-	Output
2	REGEN+	Output
Molex Mating Connector p/n: Molex Crimper tool p/n: Molex Pins p/n: Delta Tau Mating Connector p/n: Delta Tau Pins p/n:	0444412002 63811-0400 0433751001 014-000F02-HSG 014-043375-001	

6-Axis Geo Brick		
J3: Molex 3-pin Female **Mating: Molex 3-pin Male**		GBL6 GBL8 
1	CAP-	Output
2	REGEN-	Output
3	REGEN+	Output
Molex Mating Connector p/n: Molex Crimper tool p/n: Molex Pins p/n: Delta Tau Mating Connector p/n: Delta Tau Pins p/n:	0428160312 63811-1500 0433751001 014-H00F03-049 014-042815-001	

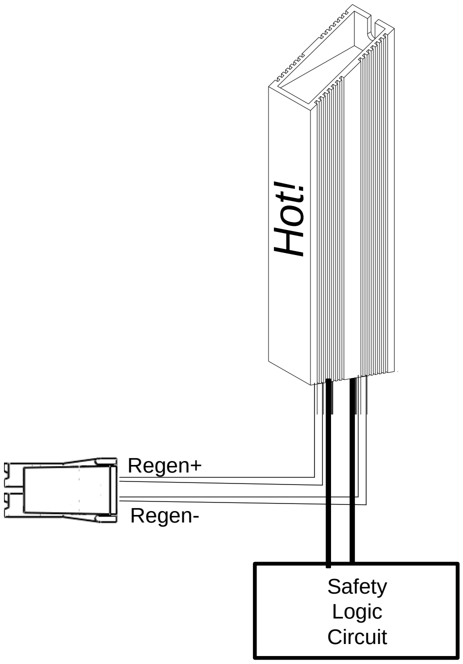
Caution

The external shunt resistors can reach temperatures of up to 200°C. They must be mounted away from other devices and ideally near the top of the cabinet, also ensure they are enclosed and cannot be touched during operation or anytime they are hot. Sufficient warning labels should be placed prominently nearby.

The black wires are for the thermostat and the white wires are for the shunt resistor.

The shunt resistor incorporates a normally closed (N.C) thermal overload protection thermostat that opens up when the core temperature of the resistor exceeds 225°C (450° F). This thermostat is accessible through the two black leads. It is important that these two leads be wired in a safety circuit to halt operation should the resistor temperature exceed the specified threshold.

The external shunt resistor Ohm rating range is found so that the minimum value limits the current to the permissible amperage, and that the maximum value limits the bus (during deceleration) to the permissible voltage.



Note

The shunt circuitry turn-on threshold is 385VDC (~272 VAC). The turn-off threshold is 360VDC (~255VAC).

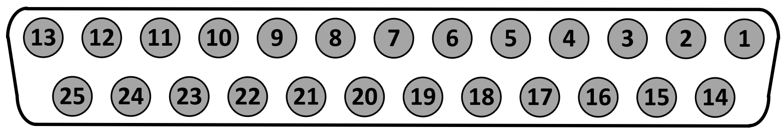
J4: Limits, Flags, EQU [Axis 1- 4]

J4 is used to wire axis/channels 1 through 4 over travel limit switches, home and user flags, and EQU output. The limits and flags can be ordered either 5V or 12-24V. The EQU output is always 5V. Per axis/channel, there are 2 limit inputs, 2 flag inputs, and 1 EQU output:
- Positive limit. Negative limit
- Home flag. User flag
- EQU

Caution

To avoid machine/equipment damage and before applying power or connecting any of the flags; make sure that your electrical design/wiring is in accordance with the Geo Brick Drive's part number option for 5- or 24-volt connection

J4: D-sub DB-25F
Mating: D-sub DB-25M



Pin #	Symbol	Function	Description
1	USER1	Input	User Flag 1
2	MLIM1	Input	Negative Limit 1
3	FL_RT1	Input	Flag Return 1
4	USER2	Input	User Flag 2
5	MLIM2	Input	Negative Limit 2
6	FL_RT2	Input	Flag Return 2
7	USER3	Input	User Flag 3
8	MLIM3	Input	Negative Limit 3
9	FL_RT3	Input	Flag Return 3
10	USER4	Input	User Flag 4
11	MLIM4	Input	Negative Limit 4
12	FL_RT4	Input	Flag Return 4
13	GND	Common	
14	PLIM1	Input	Positive Limit 1
15	HOME1	Input	Home Flag 1
16	EQU1	Output	Compare Output, EQU 1 TTL (5V) level
17	PLIM2	Input	Positive Limit 2
18	HOME2	Input	Home Flag 2
19	EQU2	Output	Compare Output, EQU 2 TTL (5V) level
20	PLIM3	Input	Positive Limit 3
21	HOME3	Input	Home Flag 3
22	EQU3	Output	Compare Output, EQU 3 TTL (5V) level
23	PLIM4	Input	Positive Limit 4
24	HOME4	Input	Home Flag 4
25	EQU4	Output	Compare Output, EQU 4 TTL (5V) level

Note

For 5V flags (internal use): Install RP39, RP43, RP47 and RP51.
1Kohm Sip, 8-pin, four independent Resistors.
For 12-24Vflags: Empty bank (Default).

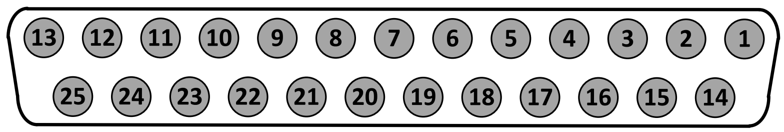
J5: Limits, Flags, EQU [Axis 5- 8]

J5 is used to wire axis/channels 5 through 8 over travel limit switches, home, user flags, and EQU output. The limits and flags can be ordered either 5V or 12-24V. The EQU output is always 5V. Per axis/channel, there are 2 limit inputs, 2 flag inputs, and 1 EQU output:
- Positive limit. Negative limit
- Home flag. User flag
- EQU

Caution

To avoid machine/equipment damage and before applying power or connecting any of the flags; make sure that your electrical design/wiring is in accordance with the Geo Brick Drive's part number option (5- or 24-volts)

J5: D-sub DB-25F
Mating: D-sub DB-25M



Pin #	Symbol	Function	Description
1	USER5	Input	User Flag 5
2	MLIM5	Input	Negative Limit 5
3	FL_RT5	Input	Flag Return 5
4	USER6	Input	User Flag 6
5	MLIM6	Input	Negative Limit 6
6	FL_RT6	Input	Flag Return 6
7	USER7	Input	User Flag 7
8	MLIM7	Input	Negative Limit 7
9	FL_RT7	Input	Flag Return 7
10	USER8	Input	User Flag 8
11	MLIM8	Input	Negative Limit 8
12	FL_RT8	Input	Flag Return 8
13	GND	Common	
14	PLIM5	Input	Positive Limit 5
15	HOME5	Input	Home Flag 5
16	BEQU5	Output	Compare Output EQU 5, TTL (5V) level
17	PLIM6	Input	Positive Limit 6
18	HOME6	Input	Home Flag 6
19	BEQU6	Output	Compare Output EQU 6, TTL (5V) level
20	PLIM7	Input	Positive Limit 7
21	HOME7	Input	Home Flag 7
22	BEQU7	Output	Compare Output EQU 7, TTL (5V) level
23	PLIM8	Input	Positive Limit 8
24	HOME8	Input	Home Flag 8
25	BEQU8	Output	Compare Output EQU 8, TTL (5V) level

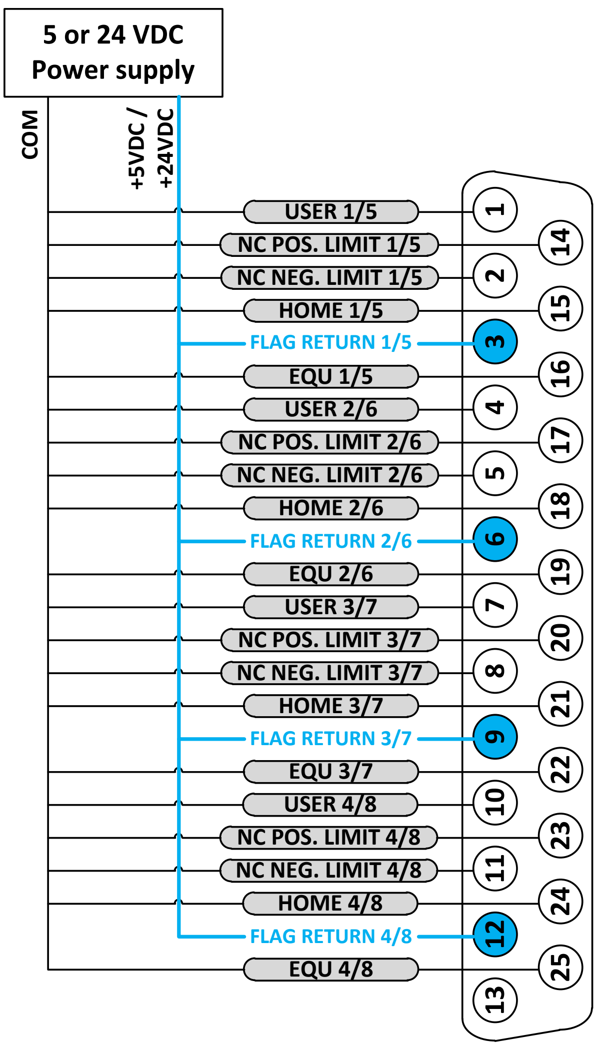
Note

For Delta Tau's internal use:
For 5V flags: Install RP89, RP93, RP97 and RP101
1Kohm Sip, 8-pin, four independent Resistors.
For 12-24Vflags: Empty bank (Default).

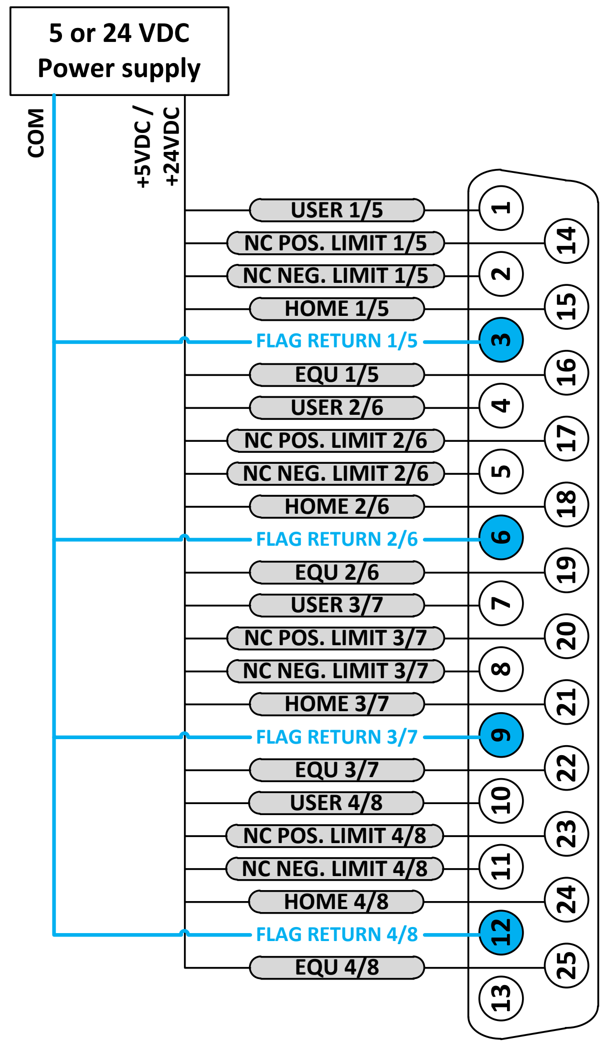
Wiring The Limits & Flags

The Geo Brick allows the use of sinking or sourcing limits and flags. The opto-isolator IC used is a **PS2705-4NEC-ND** quad phototransistor output type. This IC allows the current to flow from return to flag (sinking) or from flag to return (sourcing).

Sourcing Limits And Flags



Sinking Limits And Flags



Note

Per channel, the flags can be either sinking or sourcing depending on the flag return wiring. The over travel limits must be normally closed switches. They can be disabled (Ixx24) but they are not software configurable.

Limits & Flags [Axis 1- 4] Suggested M-Variables

```
M115->X:$078000,19     ; User 1 flag input status
M116->X:$078000,9      ; EQU1, ENC1 compare output value
M120->X:$078000,16     ; Home flag 1 input status
M121->X:$078000,17     ; Positive Limit 1 flag input status
M122->X:$078000,18     ; Negative Limit 1 flag input status

M215->X:$078008,19     ; User 2 flag input status
M216->X:$078008,9      ; EQU2, ENC2 compare output value
M220->X:$078008,16     ; Home flag 2 input status
M221->X:$078008,17     ; Positive Limit 2 flag input status
M222->X:$078008,18     ; Negative Limit 2 flag input status

M315->X:$078010,19     ; User 3 flag input status
M316->X:$078010,9      ; EQU3, ENC3 compare output value
M320->X:$078010,16     ; Home flag 3 input status
M321->X:$078010,17     ; Positive Limit 3 flag input status
M322->X:$078010,18     ; Negative Limit 3 flag input status

M415->X:$078018,19     ; User 4 flag input status
M416->X:$078018,9      ; EQU4, ENC4 compare output value
M420->X:$078018,16     ; Home flag 4 input status
M421->X:$078018,17     ; Positive Limit 4 flag input status
M422->X:$078018,18     ; Negative Limit 4 flag input status
```

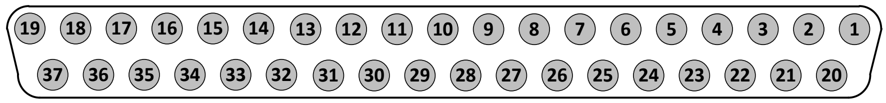
Limits & Flags [Axis 5- 8] Suggested M-Variables

```
M515->X:$078100,19     ; User 5 flag input status
M516->X:$078100,9      ; EQU5, ENC5 compare output value
M520->X:$078100,16     ; Home flag 5 input status
M521->X:$078100,17     ; Positive Limit 5 flag input status
M522->X:$078100,18     ; Negative Limit 5 flag input status

M615->X:$078108,19     ; User 6 flag input status
M616->X:$078108,9      ; EQU6, ENC6 compare output value
M620->X:$078108,16     ; Home flag 6 input status
M621->X:$078108,17     ; Positive Limit 6 flag input status
M622->X:$078108,18     ; Negative Limit 6 flag input status

M715->X:$078110,19     ; User 7 flag input status
M716->X:$078110,9      ; EQU7, ENC7 compare output value
M720->X:$078110,16     ; Home flag 7 input status
M721->X:$078110,17     ; Positive Limit 7 flag input status
M722->X:$078110,18     ; Negative Limit 7 flag input status

M815->X:$078118,19     ; User 8 flag input status
M816->X:$078118,9      ; EQU8, ENC4 compare output value
M820->X:$078118,16     ; Home flag 8 input status
M821->X:$078118,17     ; Positive Limit 8 flag input status
M822->X:$078118,18     ; Negative Limit 8 flag input status
```

J6: General Purpose Inputs/Outputs

J6 is used to wire general purpose digital inputs/outputs to the Geo Brick Drive.

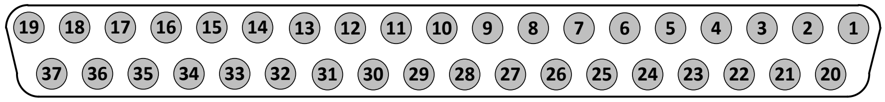
J6: D-sub DC-37F
Mating: D-sub DC-37M



Pin #	Symbol	Function	Description
1	GPI1	Input	Input 1
2	GPI3	Input	Input 3
3	GPI5	Input	Input 5
4	GPI7	Input	Input 7
5	GPI9	Input	Input 9
6	GPI11	Input	Input 11
7	GPI13	Input	Input 13
8	GPI15	Input	Input 15
9	IN_COM1-8	Common 01-08	Input 01 to 08 Common
10	N.C		Not Connected
11	COM_EMT	Input	Common Emitter
12	GP01-	Output	Sourcing Output 1
13	GP02-	Output	Sourcing Output 2
14	GP03-	Output	Sourcing Output 3
15	GP04-	Output	Sourcing Output 4
16	GP05-	Output	Sourcing Output 5
17	GP06-	Output	Sourcing Output 6
18	GP07-	Output	Sourcing Output 7
19	GP08-	Output	Sourcing Output 8
20	GPI2	Input	Input 2
21	GPI4	Input	Input 4
22	GPI6	Input	Input 6
23	GPI8	Input	Input 8
24	GPI10	Input	Input 10
25	GPI12	Input	Input 12
26	GPI14	Input	Input 14
27	GPI16	Input	Input 16
28	IN_COM9-16	Common 09-16	Input 09 to 16 Common
29	COM_COL	Input	Common Collector
30	GP01+	Output	Sinking Output 1
31	GP02+	Output	Sinking Output 2
32	GP03+	Output	Sinking Output 3
33	GP04+	Output	Sinking Output 4
34	GP05+	Output	Sinking Output 5
35	GP06+	Output	Sinking Output 6
36	GP07+	Output	Sinking Output 7
37	GP08+	Output	Sinking Output 8

J7: General Purpose Inputs/Outputs (Additional)

J7 is used to wire the additional (optional) general purpose digital Inputs/Outputs to the Geo Brick.

J7: D-sub DC-37F **Mating: D-sub DC-37M**			
Pin #	**Symbol**	**Function**	**Description**
1	GPI17	Input	Input 17
2	GPI19	Input	Input 19
3	GPI21	Input	Input 21
4	GPI23	Input	Input 23
5	GPI25	Input	Input 25
6	GPI27	Input	Input 27
7	GPI29	Input	Input 29
8	GPI31	Input	Input 31
9	IN_COM 17-24	Common 17-24	Input 17 to 24 Common
10	N.C		Not Connected
11	COM_EMT	Input	Common Emitter
12	GPO9-	Output	Sourcing Output 9
13	GPO10-	Output	Sourcing Output 10
14	GPO11-	Output	Sourcing Output 11
15	GPO12-	Output	Sourcing Output 12
16	GPO13-	Output	Sourcing Output 13
17	GPO14-	Output	Sourcing Output 14
18	GPO15-	Output	Sourcing Output 15
19	GPO16-	Output	Sourcing Output 16
20	GPI18	Input	Input 18
21	GPI20	Input	Input 20
22	GPI22	Input	Input 22
23	GPI24	Input	Input 24
24	GPI26	Input	Input 26
25	GPI28	Input	Input 28
26	GPI30	Input	Input 30
27	GPI32	Input	Input 32
28	IN_COM_25-32	Common 25-32	Input 25 to 32 Common
29	COM_COL	Input	Common Collector
30	GPO9+	Output	Sinking Output 9
31	GPO10+	Output	Sinking Output 10
32	GPO11+	Output	Sinking Output 11
33	GPO12+	Output	Sinking Output 12
34	GPO13+	Output	Sinking Output 13
35	GPO14+	Output	Sinking Output 14
36	GPO15+	Output	Sinking Output 15
37	GPO16+	Output	Sinking Output 16

Wiring The General Purpose Inputs And Outputs

All general purpose inputs and outputs are optically isolated. They operate in the 12–24 VDC range, and can be wired to be either sinking or sourcing.

The inputs use the **PS2505L-1NEC** photocoupler.
For sourcing inputs, connect the input common pin(s) to the 12–24V line of the power supply. The input devices are then connected to the common ground line of the power supply at one end, and individual input pins at the other.
For sinking inputs, connect the input common pin(s) to the common ground line of the power supply. The input devices are then connected to the 12–24V line of the power supply at one end, and individual input pins at the other.

Note

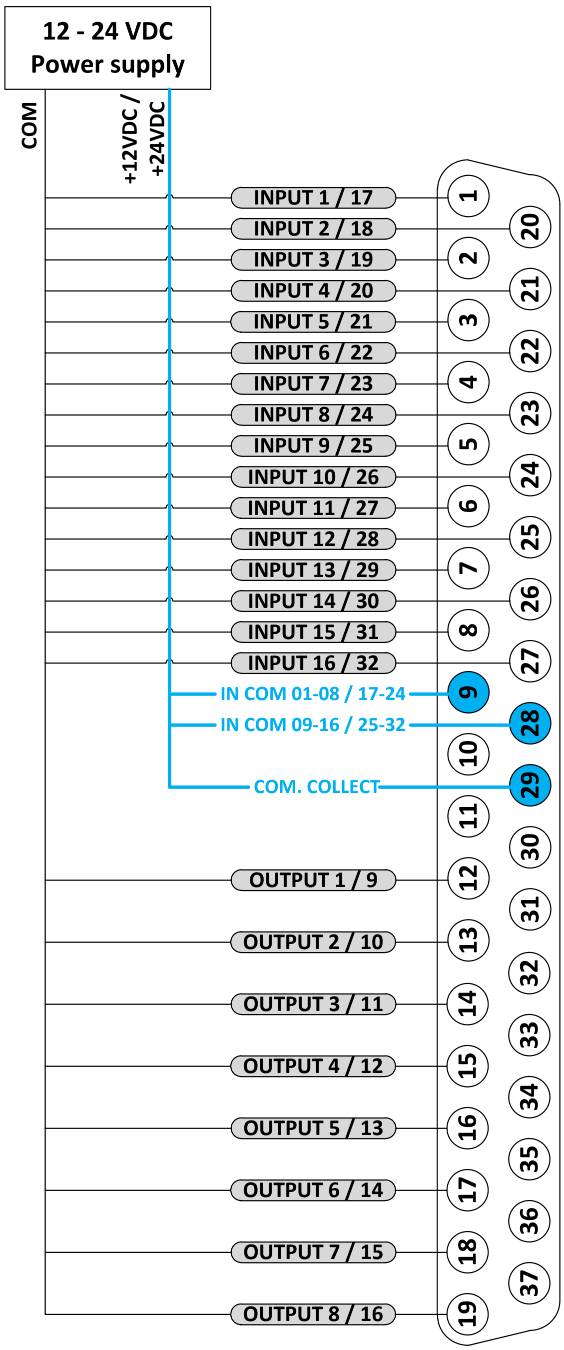
The inputs can be wired either sourcing or sinking in sets of eight, with each set possessing its own common.

The outputs use the **PS2501L-1NEC** photocoupler. They are rated to a maximum current of 500 mA, and are overload protected.
For sourcing outputs, connect the common collector (pin #29) to the 12–24V line of the power supply. The output devices are then connected to the common ground line of the power supply at one end, and individual sourcing output pins at the other.
For sinking outputs, connect the common emitter (pin #11) to the common ground line of the power supply. The output devices are then connected to the 12–24V line of the power supply at one end, and individual sinking output pins at the other.

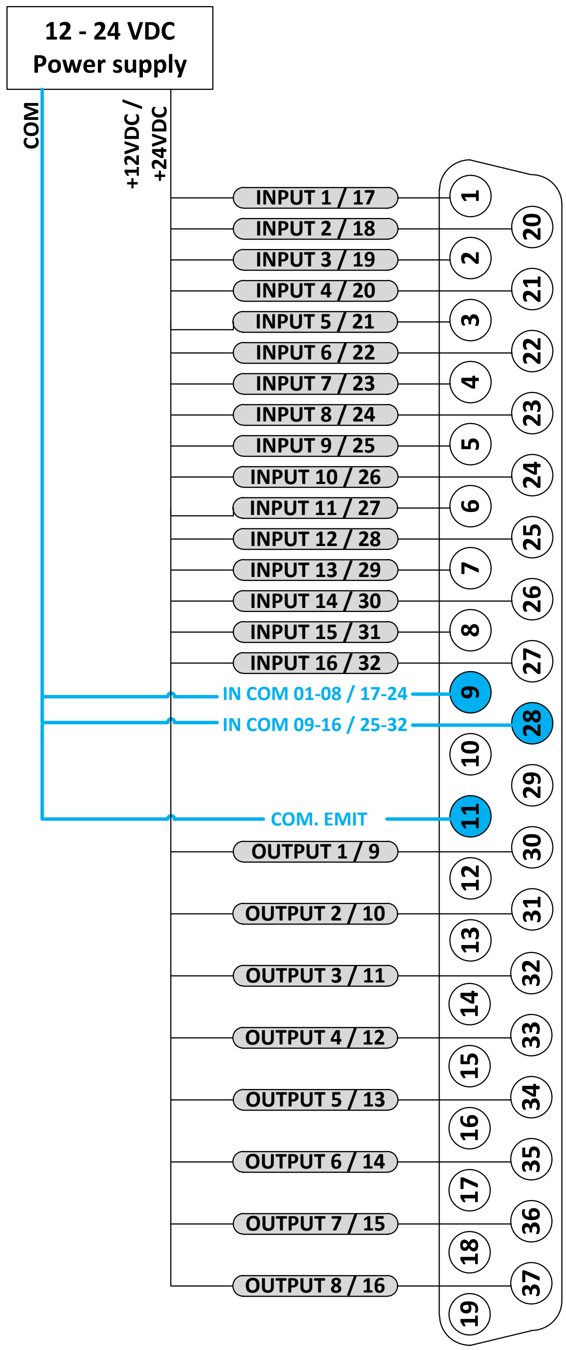
Note

Do not mix topologies for outputs. They are all either sinking or sourcing. If the common emitter is used, the common collector should not be connected and vice versa.

Sourcing Inputs
Sourcing Outputs



Sinking Inputs
Sinking Outputs



General Purpose I/Os (J6) Suggested M-Variables

```
// Inputs:
M1->Y:$78800,0,1       ; Input 01 J6 Pin#1
M2->Y:$78800,1,1       ; Input 02 J6 Pin#20
M3->Y:$78800,2,1       ; Input 03 J6 Pin#2
M4->Y:$78800,3,1       ; Input 04 J6 Pin#21
M5->Y:$78800,4,1       ; Input 05 J6 Pin#3
M6->Y:$78800,5,1       ; Input 06 J6 Pin#22
M7->Y:$78800,6,1       ; Input 07 J6 Pin#4
M8->Y:$78800,7,1       ; Input 08 J6 Pin#23
M9->Y:$78801,0,1       ; Input 09 J6 Pin#5
M10->Y:$78801,1,1      ; Input 10 J6 Pin#24
M11->Y:$78801,2,1      ; Input 11 J6 Pin#6
M12->Y:$78801,3,1      ; Input 12 J6 Pin#25
M13->Y:$78801,4,1      ; Input 13 J6 Pin#7
M14->Y:$78801,5,1      ; Input 14 J6 Pin#26
M15->Y:$78801,6,1      ; Input 15 J6 Pin#8
M16->Y:$78801,7,1      ; Input 16 J6 Pin#27

//Outputs:               Output#      Sourcing       Sinking
M33->Y:$078802,0,1     ; Output 1 J6  Pin#12         Pin#30
M34->Y:$078802,1,1     ; Output 2 J6  Pin#13         Pin#31
M35->Y:$078802,2,1     ; Output 3 J6  Pin#14         Pin#32
M36->Y:$078802,3,1     ; Output 4 J6  Pin#15         Pin#33
M37->Y:$078802,4,1     ; Output 5 J6  Pin#16         Pin#34
M38->Y:$078802,5,1     ; Output 6 J6  Pin#17         Pin#35
M39->Y:$078802,6,1     ; Output 7 J6  Pin#18         Pin#36
M40->Y:$078802,7,1     ; Output 8 J6  Pin#19         Pin#37
```

General Purpose I/Os Additional (J7) Suggested M-Variables

```
// Inputs:
M17->Y:$78803,0,1      ; Input 17 J7 Pin#1
M18->Y:$78803,1,1      ; Input 18 J7 Pin#20
M19->Y:$78803,2,1      ; Input 19 J7 Pint#2
M20->Y:$78803,3,1      ; Input 20 J7 Pin#21
M21->Y:$78803,4,1      ; Input 21 J7 Pin#3
M22->Y:$78803,5,1      ; Input 22 J7 Pin#22
M23->Y:$78803,6,1      ; Input 23 J7 Pin#4
M24->Y:$78803,7,1      ; Input 24 J7 Pin#23
M25->Y:$78804,0,1      ; Input 25 J7 Pin#5
M26->Y:$78804,1,1      ; Input 26 J7 Pin#24
M27->Y:$78804,2,1      ; Input 27 J7 Pin#6
M28->Y:$78804,3,1      ; Input 28 J7 Pin#25
M29->Y:$78804,4,1      ; Input 29 J7 Pin#7
M30->Y:$78804,5,1      ; Input 30 J7 Pin#26
M31->Y:$78804,6,1      ; Input 31 J7 Pin#8
M32->Y:$78804,7,1      ; Input 32 J7 Pin#27

//Outputs:               Output#       Sourcing      Sinking
M41->Y:$078805,0,1     ; Output 09 J7  Pin#12        Pin#30
M42->Y:$078805,1,1     ; Output 10 J7  Pin#13        Pin#31
M43->Y:$078805,2,1     ; Output 11 J7  Pin#14        Pin#32
M44->Y:$078805,3,1     ; Output 12 J7  Pin#15        Pin#33
M45->Y:$078805,4,1     ; Output 13 J7  Pin#16        Pin#34
M46->Y:$078805,5,1     ; Output 14 J7  Pin#17        Pin#35
M47->Y:$078805,6,1     ; Output 15 J7  Pin#18        Pin#36
M48->Y:$078805,7,1     ; Output 16 J7  Pin#19        Pin#37
```

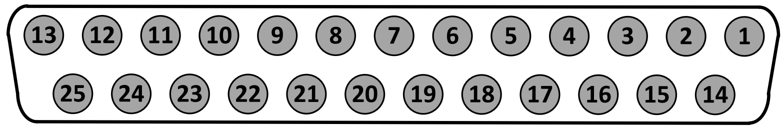
J8: PWM Amplifier Interface

J8 is used to connect to third party PWM amplifiers. This is a limited option, contact technical support for setup details.

J9: Handwheel Analog I/O (Optional)

J9 is used to wire the additional analog inputs, handwheel encoder, analog output, and PFM output.

J9: D-sub DB-25F
Mating: D-sub DB-25M



Pin #	Symbol	Function	Notes
1	AIN1	Input	Analog Input #1
2	AIN3	Input	Analog Input #3
3	AIN5	Input	Analog Input #5
4	AIN7	Input	Analog Input #7
5	+12V	Output	For troubleshooting (no practical use)
6	GND	Common	Common Ground
7	ANAOUT-	Output	Analog Output -
8	PULSE-	Output	Pulse Output -
9	DIR-	Output	Direction Output -
10	HWA+	Input	Handwheel Quadrature A
11	HWB+	Input	Handwheel Quadrature B
12	HWC+	Input	Handwheel Quadrature C
13	+5V	Output	For troubleshooting (no practical use)
14	AIN2	Input	Analog Input #2
15	AIN4	Input	Analog Input #4
16	AIN6	Input	Analog Input #6
17	AIN8	Input	Analog Input #8
18	-12V	Output	For troubleshooting (no practical use)
19	ANAOUT+	Output	Analog Output +
20	PULSE+	Output	Pulse Output +
21	DIR+	Output	Direction Output +
22	GND	Common	Common Ground
23	HWA-	Input	Handwheel Quadrature A/
24	HWB-	Input	Handwheel Quadrature B/
25	HWC-	Input	Handwheel Quadrature C/

Note

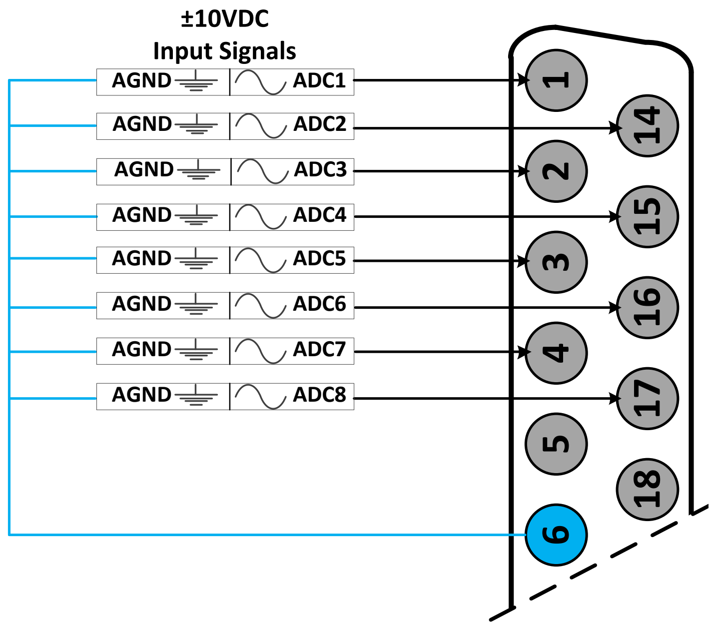
Addressing in a glance:
Analog Inputs at Y:$78B40 using PMAC option12.
Analog Output at Y:$78412,8,16,S using Supp. Ch1* Output A.
Pulse and Direction at Y:$7841C,8,16,S using Supp. Ch2* Output C.
Handwheel Input at Y:$78410 using Supp. Ch1* Handwheel.

Setting Up The Analog Inputs (J9)

The J9 port can be used to bring in eight multiplexed 12-bit single-ended analog inputs using the traditional Option 12.

These analog inputs can be used either in unipolar mode in the 0V to +10V range, or bipolar mode in the -10V to +10V range.

Each input has a 470Ω input resistor in-line, and a 0.01 µF resistor to ground ensuing a 4.7 µsec time constant per input line.




```
I5060=8          ; Copy 8 ADC pairs
I5061=$000340    ; ADC1 is referenced to $078800+$000340= $78B40
I5062=$000340    ; ADC2 is referenced to $078800+$000340= $78B40
I5063=$000340    ; ADC3 is referenced to $078800+$000340= $78B40
I5064=$000340    ; ADC4 is referenced to $078800+$000340= $78B40
I5065=$000340    ; ADC5 is referenced to $078800+$000340= $78B40
I5066=$000340    ; ADC6 is referenced to $078800+$000340= $78B40
I5067=$000340    ; ADC7 is referenced to $078800+$000340= $78B40
I5068=$000340    ; ADC8 is referenced to $078800+$000340= $78B40
```

Bipolar Mode

```
I5081=$000008 ; ADC1 Bipolar
I5082=$000009 ; ADC2 Bipolar
I5083=$00000A ; ADC3 Bipolar
I5084=$00000B ; ADC4 Bipolar
I5085=$00000C ; ADC5 Bipolar
I5086=$00000D ; ADC6 Bipolar
I5087=$00000E ; ADC7 Bipolar
I5088=$00000F ; ADC8 Bipolar
```

Unipolar Mode

```
I5081=$000000 ; ADC1 Unipolar
I5082=$000001 ; ADC2 Unipolar
I5083=$000002 ; ADC3 Unipolar
I5084=$000003 ; ADC4 Unipolar
I5085=$000004 ; ADC5 Unipolar
I5086=$000005 ; ADC6 Unipolar
I5087=$000006 ; ADC7 Unipolar
I5088=$000007 ; ADC8 Unipolar
```

Note

- A **SAVE** and a reset (**$$$**) is required to initialize this function properly after download.
- In Unipolar mode, the ADCs can measure up to 12V since the op-amps are powered with 12VDC.

J9 Analog Inputs Suggested M-Variables

Bipolar Mode (Signed)

```
M7071->Y:$003400,12,12,S ; ADC 1
M7072->Y:$003402,12,12,S ; ADC 2
M7073->Y:$003404,12,12,S ; ADC 3
M7074->Y:$003406,12,12,S ; ADC 4
M7075->Y:$003408,12,12,S ; ADC 5
M7076->Y:$00340A,12,12,S ; ADC 6
M7077->Y:$00340C,12,12,S ; ADC 7
M7078->Y:$00340E,12,12,S ; ADC 8
```

Unipolar Mode (Unsigned)

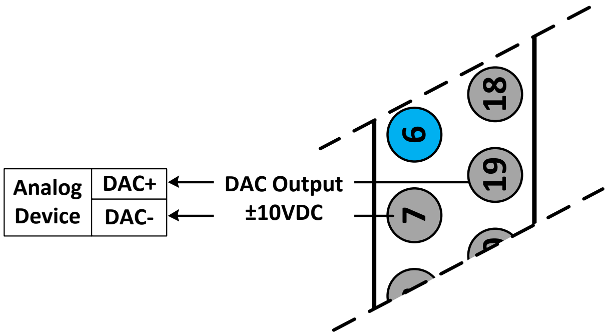
```
M7081->Y:$003400,12,12,U ; ADC 1
M7082->Y:$003402,12,12,U ; ADC 2
M7083->Y:$003404,12,12,U ; ADC 3
M7084->Y:$003406,12,12,U ; ADC 4
M7085->Y:$003408,12,12,U ; ADC 5
M7086->Y:$00340A,12,12,U ; ADC 6
M7087->Y:$00340C,12,12,U ; ADC 7
M7088->Y:$00340E,12,12,U ; ADC 8
```

Testing The J9 Analog Inputs

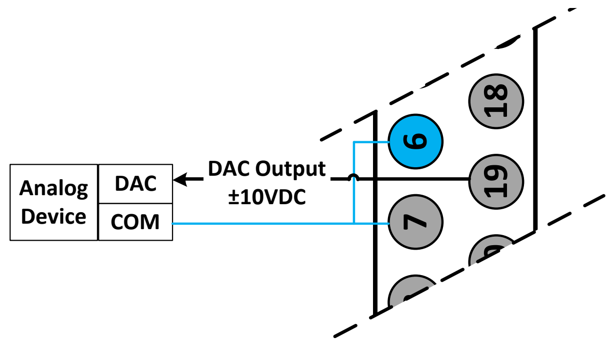
<table>
<tr><th></th><th></th><th>Input Voltage</th><th>Software Counts</th></tr>
<tr><td rowspan="2"></td><td rowspan="5">Bipolar</td><td>-10</td><td>-2048</td></tr>
<tr><td>-5</td><td>-1024</td></tr>
<tr><td rowspan="3">Unipolar</td><td>0</td><td>0</td></tr>
<tr><td>+5</td><td>+1024</td></tr>
<tr><td>+10</td><td>+2048</td></tr>
</table>

Setting Up The Analog Output (J9)

Differential Output



Single-Ended Output



This option provides one 12-bit filtered PWM output.
A fully populated Brick unit can have one of three clock generators (gates); Servo IC0, Servo IC1, and MACRO IC0. Variable I19 specifies which gate is used as the master gate providing phase and servo clocks. In Geo Brick Drives, Servo IC0 is the Master by default (i.e. I19=7007).
The J9 analog output option is on MACRO IC0. The relationship between the PWM clock setting of MACRO IC0 and the master gate (normally Servo IC0) should always be respected, such as:

$$f_{\text{PWM (Clock Recipients)}} = \frac{n}{2} f_{\text{PHASE (Clock Generator)}} \qquad \text{Where n is an integer}$$

A PWM frequency in the range of 25-40 KHz provides with a minimum-ripple Analog Output (filtered PWM) signal. Additionally, a PWM dead time of zero is recommended for filtered PWM operation.

Examples:
For a Geo Brick Drive at default clock settings and master gate Servo IC0 (I19=7007), MACRO IC0 settings for a good analog output should be:

Servo IC0	Generator Clocks [KHz]	
I7000=6527	PWM	4.5
I7001=0	PHASE	9
I7002=3	SERVO	2.25
I10=3713991		

MACRO IC0	Recipient Clocks [KHz]	
I6800=816	PWM	36
I6801=7	PHASE	9
I6802=3	SERVO	2.25
I6804=0	$PWM_{Deadtime}$	0

n=8 in this case

For a Geo Brick Drive at enhanced clock settings and master gate Servo IC0 (I19=7007), MACRO IC0 settings for a good analog output should be:

Servo IC0	Generator Clocks [KHz]	
I7000=3275	PWM	9
I7001=0	PHASE	18
I7002=3	SERVO	4.5
I10=1863964		

MACRO IC0	Recipient Clocks [KHz]	
I6800=816	PWM	36
I6801=3	PHASE	18
I6802=3	SERVO	4.5
I6804=0	$PWM_{Deadtime}$	0

n=4 in this case

Note

These MACRO IC0 Clock settings are optimized for a good Analog Output signal. If the Brick is a MACRO Ring Controller then the analog output signal quality is compromised with a much lower PWM frequency, or not used at all.

For Help with clock settings, use Delta Tau Calculator: **DT Calculator Forum Link**

J9 Analog Output Suggested M-Variable

```
// I/O 10 & 11 Mode (PWM)
M7051->Y:$78404,10,1
M7052->Y:$78404,11,1
M7051=0         ; =0 PWM, =1 PFM
M7052=0         ; =0 PWM, =1 PFM

// Analog Output M-variable
M7050->Y:$78412,8,16,S

// These I/O nodes have to be setup once on power-up.
// power-up PLC Example
Open PLC 1 clear
I6612=100*8388608/I10 While(I6612>0) Endw
M7051=0 ; PWM mode
M7052=0 ; PWM mode
Disable PLC 1
Close
```

Testing the J9 Analog Output

With I6800=816, writing directly to the assigned M-variable (e.g. M7050) should produce the following:

M7050	**Single-Ended: Gnd ⇔ Output+**	**Differential: Output+ ⇔ Output-**
	-10V	-20V
-408	-5V	-10V
0	0V	0V
408	+5V	+10V
816	+10V	+20V

Note

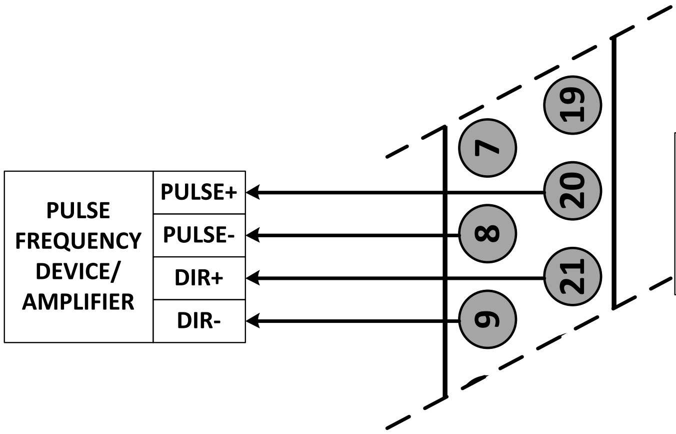
Writing values greater than I6800 (i.e. 816) in M7050 will saturate the output to 10, or 20 volts in single-ended or differential mode respectively.

Note

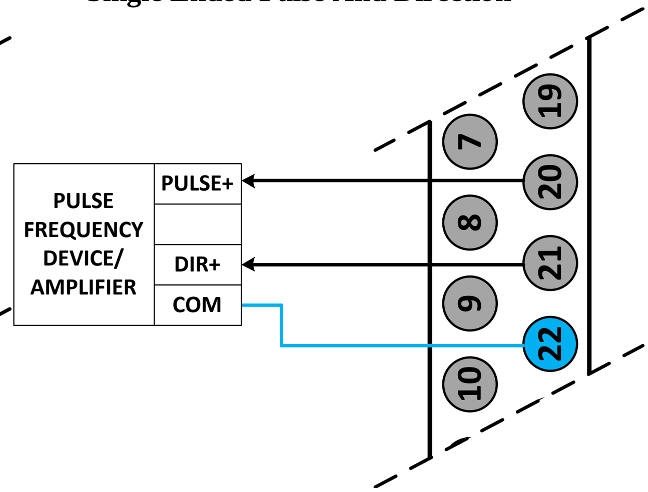
MACRO connectivity provides a cleaner solution for analog outputs, e.g. ACC-24M2A.

Setting Up Pulse And Direction Output PFM (J9)

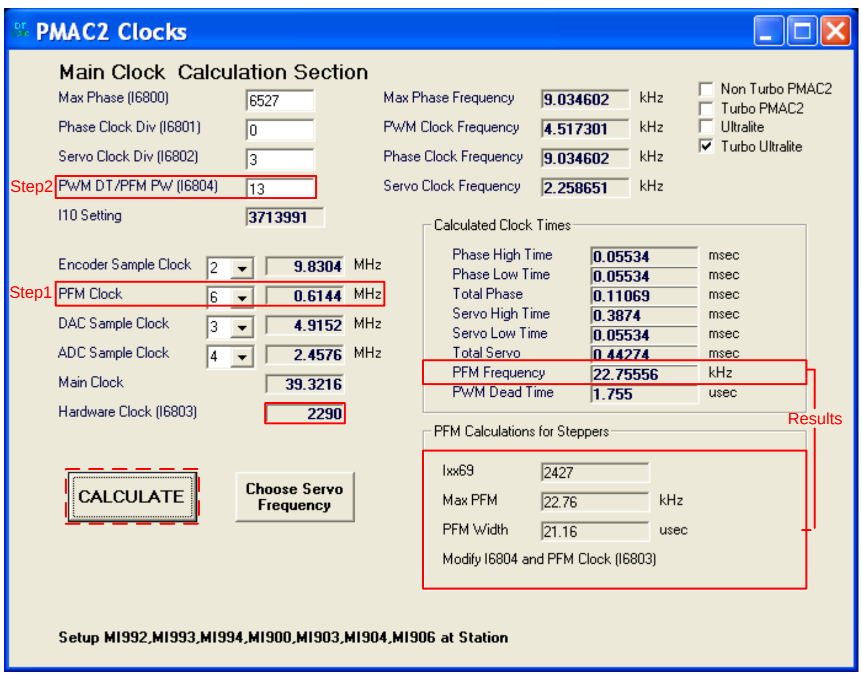
Differential Pulse And Direction



Single Ended Pulse And Direction



Using the Delta Tau Calculator or referring to the Turbo Software Reference Manual, the desired maximum PFM Frequency and pulse width can be chosen. **DT Calculator**



Step 1: Choose Max PFM clock by changing the PFM clock divider. Click on calculate to see results.
Step 2: Choose PFM Pulse width by changing I6804. Click on calculate to see results.

For a PFM clock range 0-20 KHz, and a pulse width of ~20 µsec:

```
I6803=2290              ; PFM Clock divider equal to 6
I6804=13                ; PFM Pulse Width Control equal to 13
```

The output frequency control Ixx69 specifies the maximum command output value that corresponds to the maximum PFM Frequency.

```
I6826=3                ; MACRO IC Channel2 Output Mode Select. C PFM
M8000->Y:$7841C,8,16,S ; Supplementary Channel 2* Output C Command Value
                       ; Min=0, Max= Calculated Ixx69
M8001->X:$7841D,21     ; Invert C Output Control. 0=no inversion, 1=invert
```

Testing The J9 PFM Output

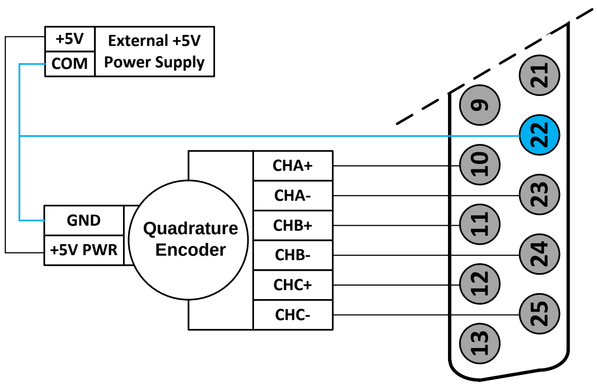
Writing, directly to the suggested M-variable (i.e. M8000), values proportional to the calculated Ixx69, produces the following corresponding frequencies:

M8000	PFM [KHz]
0	0
1213	11
2427	22

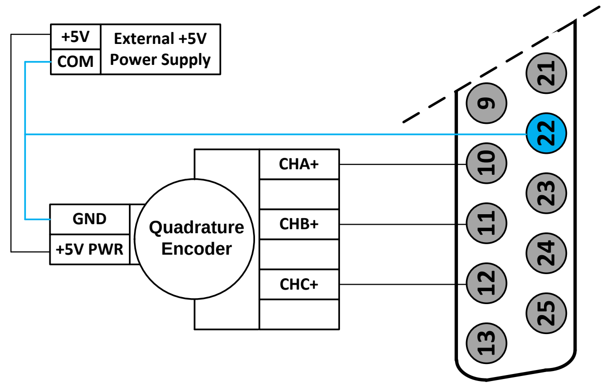
Setting Up The Handwheel Port (J9)

A quadrature encoder type device is normally brought into the handwheel port; it can be wired and used in either single-ended or differential mode. The encoder power is not provided for this device, it must be brought in externally.

Differential Handwheel



Single ended Handwheel



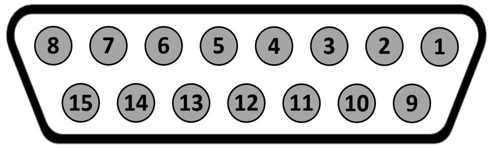
The encoder data can be brought into the Encoder Conversion Table allowing direct access with an M-variable or used as a master position (Ixx05) for a specific motor.

Example:

```
I8000=$78410            ; ECT Entry 1: 1/T extension of location $78410
M8000->X:$3501,0,24,S  ; ECT 1st entry result
```

X1-X8: Encoder Feedback, Digital A Quad B

X1-X8: D-sub DA-15F
Mating: D-sub DA-15M



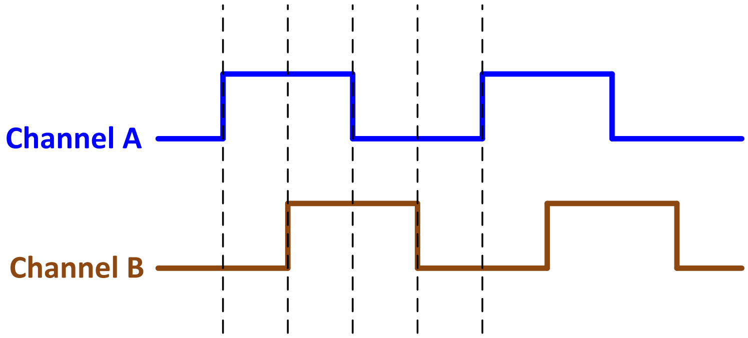
Pin#	Symbol	Function	Description
1	CHA+	Input	Encoder A+
2	CHB+	Input	Encoder B+
3	CHC+ / AENA+	Input	Encoder Index+ / Stepper amp enable +
4	ENCPWR	Output	Encoder Power 5V
5	CHU+ / DIR+	In/Out	Halls U+ / Direction Output + for Stepper
6	CHW+/ PUL+	In/Out	Halls W+ / Pulse Output + for Stepper
7	2.5V	Output	2.5V Reference power
8	Stepper Enable	Input	Tie to pin#4 (5V) to enable PFM output
9	CHA-	Input	Encoder A-
10	CHB-	Input	Encoder B-
11	CHC- / AENA-	Input	Encoder Index- / Stepper amp enable -
12	GND	Common	Common ground
13	CHV+ / DIR-	In/Out	Halls V+ / Direction Output- for Stepper
14	CHT+ / PUL-	In/Out	Halls T+ / Pulse Output- for Stepper
15	-	-	Unused

Note

Use an encoder cable with high quality shield. Connect the shield to connector shell, and use ferrite core in noise sensitive environments.

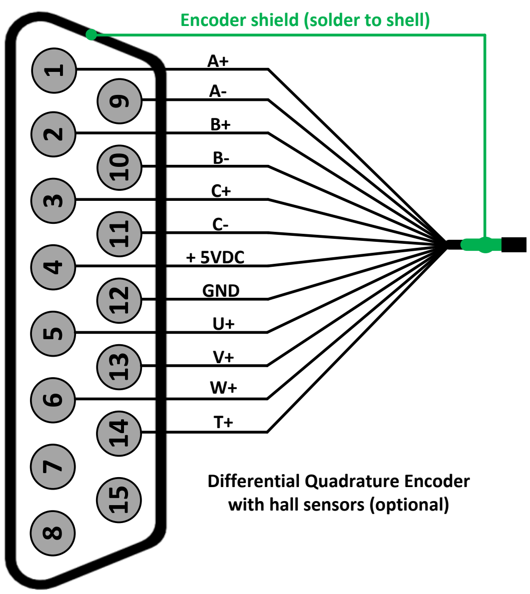
The standard encoder inputs on the Geo Brick Drive are designed for differential quadrature type signals.

Quadrature encoders provide two digital signals to determine the position of the motor. Each nominally with 50% duty cycle, and nominally 1/4 cycle apart. This format provides four distinct states per cycle of the signal, or per line of the encoder. The phase difference of the two signals permits the decoding electronics to discern the direction of travel, which would not be possible with a single signal.

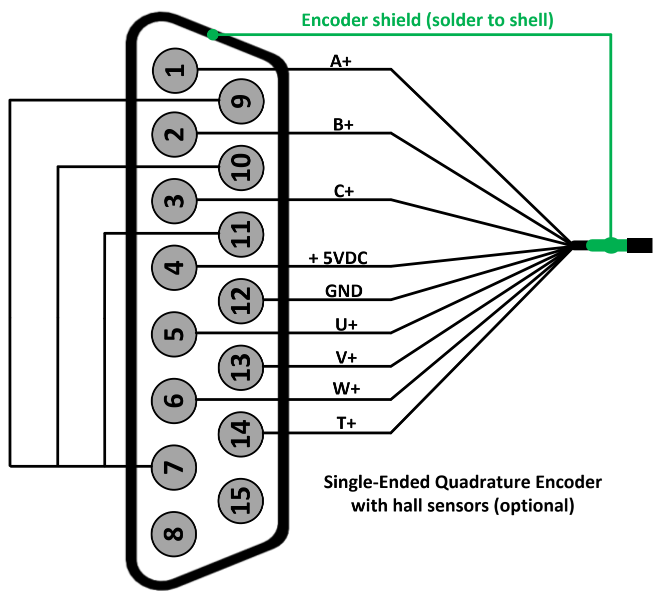


Typically, these signals are 5V TTL/CMOS level whether they are single-ended or differential. Differential signals can enhance noise immunity by providing common mode noise rejection. Modern design standards virtually mandate their use in industrial systems.

Differential Quadrature Encoder Wiring



Single-Ended Quadrature Encoder Wiring



Note	For single-ended encoders, tie the negative pins to power reference (Pin#7). Alternately, some open collector single ended encoders may require tying the negative pins to ground in series with a 1-2 KOhm resistors.

Note	Some motor manufacturers bundle the hall sensors with the motor-lead cable. The hall sensors must be brought into this connector for setup simplicity.

Setting Up Quadrature Encoders

Digital Quadrature Encoders use the 1/T incremental entry in the encoder conversion table. Position and velocity pointers should, by default, be valid and in most cases no software setup is required, activating (Ixx00=1) the corresponding channel is sufficient to see encoder counts in the position window when the motor/encoder shaft is moved by hand.

```
I100,8,100=1    ; Channels 1-8 activated
```

Encoder Count Error (Mxx18)

The Geo Brick Drive has an encoder count error detection feature. If both the A and B channels of the quadrature encoder change state at the decode circuitry (post-filter) in the same hardware sampling clock (SCLK) cycle, an unrecoverable error to the counter value will result (lost counts). Suggested M-Variable Mxx18 for this channel is then set and latched to 1 (until reset or cleared). The three most common root causes of this error:

- Real encoder hardware problem
- Trying to move the encoder (motor) faster than it's specification
- Using an extremely high resolution/speed encoder. This may require increasing the SCLK

The default sampling clock in the Geo Brick Drive is ~ 10MHz, which is acceptable for virtually all applications. A setting of I7mn3 of 2257 (from default of 2258) sets the sampling clock SCLK at about ~20MHz. It can be increased to up to ~40 MHz.

Note

No automatic action is taken by the Geo Brick Drive if the encoder count error bit is set.

Encoder Loss Detection, Quadrature

Designed for use with differential line-driver outputs (encoders), the encoder loss circuitry monitors each quadrature input pair with an exclusive-or XOR gate. In normal operation mode, the two quadrature inputs should be in opposite logical states – that is one high and one low – yielding a true output from the XOR gate.

Note

Single-Ended Quadrature Encoders are not supported for encoder loss.

Ch#	Address/Definition
1	Y:$78807,0,1
2	Y:$78807,1,1
3	Y:$78807,2,1
4	Y:$78807,3,1

Ch#	Address/Definition
5	Y:$78807,4,1
6	Y:$78807,5,1
7	Y:$78807,6,1
8	Y:$78807,7,1

Status Bit	Definition
=0	Encoder lost, Fault
=1	Encoder present, no Fault

Caution

Appropriate action (user-written plc) needs to be implemented when an encoder loss is encountered. To avoid a runaway, an immediate Kill of the motor/encoder in question is strongly advised.

No automatic firmware (Geo Brick) action is taken upon detection of encoder(s) loss; it is the user's responsibility to perform the necessary action to make the application safe under these conditions, see example PLC below. Killing the motor/encoder in question is the safest action possible, and strongly recommended to avoid a runaway, and machine damage. Also, the user should decide the action to be taken (if any) for the other motors in the system. The Encoder Loss Status bit is a low true logic. It is set to 1 under normal conditions, and set to 0 when a fault (encoder loss) is encountered.

Encoder Loss Example PLC:

A 4-axis Geo Brick is setup to kill all motors upon the detection of one or more encoder loss. In addition, it does not allow enabling any of the motors when an encoder loss condition has been encountered:

```
#define Mtr1AmpEna            M139   ; Motor#1 Amplifier Enable Status Bit
Mtr1AmpEna->X:$B0,19                 ; Suggested M-Variable
#define Mtr2AmpEna            M239   ; Motor#2 Amplifier Enable Status Bit
Mtr2AmpEna->X:$130,19                ; Suggested M-Variable
#define Mtr3AmpEna            M339   ; Motor#3 Amplifier Enable Status Bit
Mtr3AmpEna->X:$1B0,19                ; Suggested M-Variable
#define Mtr4AmpEna            M439   ; Motor#4 Amplifier Enable Status Bit
Mtr4AmpEna->X:$230,19                ; Suggested M-Variable

#define Mtr1EncLoss           M180   ; Motor#1 Encoder Loss Status Bit
Mtr1EncLoss->Y:$078807,0,1           ;
#define Mtr2EncLoss           M280   ; Motor#2 Encoder Loss Status Bit
Mtr2EncLoss->Y:$078807,1,1           ;
#define Mtr3EncLoss           M380   ; Motor#3 Encoder Loss Status Bit
Mtr3EncLoss->Y:$078807,2,1           ;
#define Mtr4EncLoss           M480   ; Motor#4 Encoder Loss Status Bit
Mtr4EncLoss->Y:$078807,3,1           ;

#define SysEncLoss            P1080  ; System Global Encoder Loss Status (user defined)
SysEncLoss=0                         ; Save and Set to 0 at download, normal operation
                                     ; =1 System Encoder Loss Occurred

OPEN PLC 1 CLEAR
If (SysEncLoss=0)      ; No Loss yet, normal mode
 If (Mtr1EncLoss=0 or Mtr2EncLoss=0 or Mtr4EncLoss=0 or Mtr4EncLoss=0)
  CMD^K                ; One or more Encoder Loss(es) detected, kill all motors
  SysEncLoss=1         ; Set Global Encoder Loss Status to Fault
 EndIf
EndIF

If (SysEncLoss=1)      ; Global Encoder Loss Status At Fault?
 If (Mtr1AmpEna=1 or Mtr2AmpEna=1 or Mtr4AmpEna=1 or Mtr4AmpEna=1) ; Trying to Enable Motors?
  CMD^K                ; Do not allow Enabling Motors, Kill all
 EndIF
EndIF
CLOSE
```

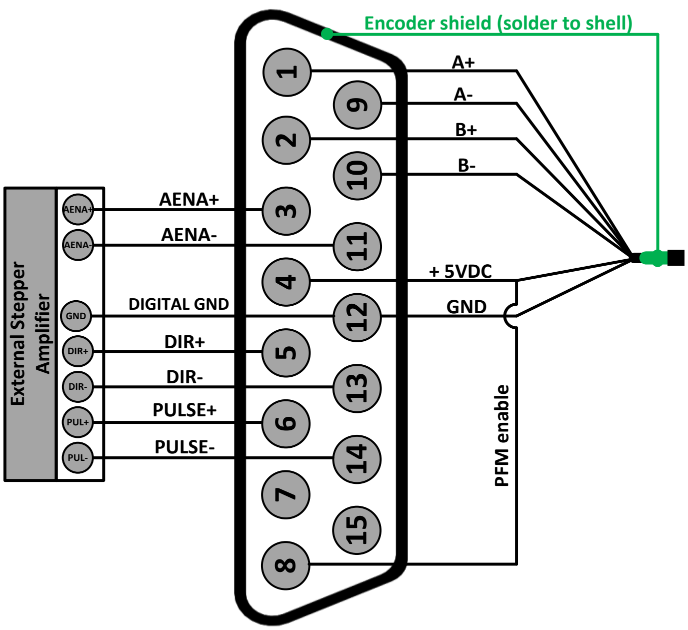
Step and Direction PFM Output (To External Stepper Amplifier)

The Geo Brick Drive has the capability of generating step and direction (Pulse Frequency Modulation) output signals to external stepper amplifiers. These signals are accessible at the encoder connectors. The step and direction outputs are RS422 compatible and could be connected in either differential or single-ended configuration for 5V (input signal) amplifiers.

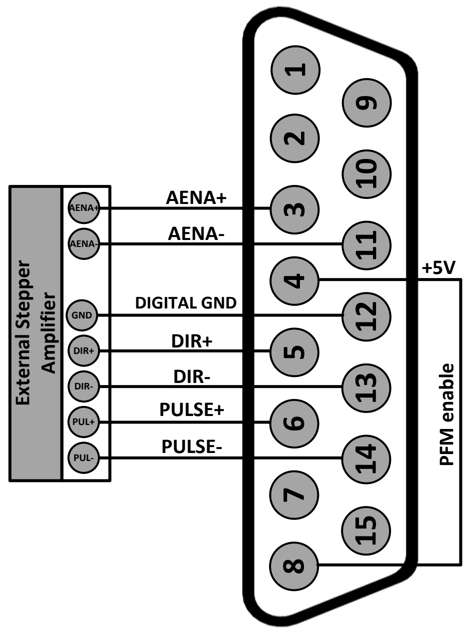
Note	Quadrature encoders can still be used in this mode. However, hall sensors can NOT be brought into this connector. The corresponding pins are shared with the PFM circuitry. Additionally, if an amplifier enable output signal is required, the index (C-channel) of the quadrature encoder cannot be used.

Note	The default mode does not provide a PFM amplifier enable output signal. This should be requested upon ordering the Geo Brick Drive to avoid changing jumper settings internal to the drive, and risk losing product warranty in the process.

PFM output to stepper amplifier with encoder feedback



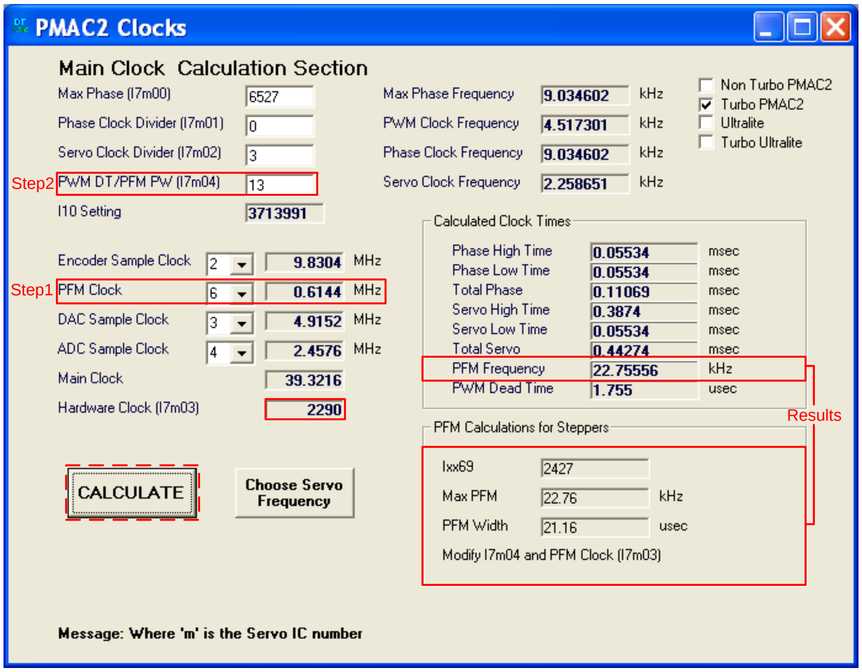
PFM output to stepper amplifier without encoder feedback



Note	Tie pin#8 to pin#4 (+5V) to enable PFM signal output.

For Delta Tau internal use:
Install Jumpers E25, E26, E27, and E28 to activate amp enable on channels 1 through 4 respectively.
Install Jumpers E35, E36, E37, and E38 to activate amp enable on channels 5 through 8 respectively.

Using the Delta Tau Calculator or referring to the Turbo Software Reference Manual, the desired maximum PFM Frequency and pulse width can be chosen. **DT Calculator**



Step 1: Choose Max PFM clock by changing the PFM clock divider. Press calculate to see results.
Step 2: Choose PFM pulse width by changing I7m04. Press calculate to see results.

Example: Axis 5-8 are driving 4 stepper drives, and require a PFM clock range of 0-20 KHz and a pulse width of ~20 μsec:

```
// Servo IC #1 global I-variables:
I7100=6527              ; Servo IC #1 Max Phase Clock (default)
I7101=0                 ; Servo IC #1 Phase Clock Divider (default)
I7102=3                 ; Servo IC #1 Servo Clock Divider (default)
I7103=2290              ; Servo IC #1 PFM Clock divider
I7104=13                ; Servo IC #1 PFM Pulse Width Control

// Servo IC/Channel I-variables:
I7110,4,10=8            ; Internal pulse and direction on channel 5 thru 8
I7116,4,10=2            ; C-channel mode PFM for channel 5 thru 8

// Motor Activation
I500,4,100=1            ; Motors 5-8 Activated

// Output Command Limit
I569,4,100=2427         ; Motors 5-8 Output Command Limit (from calculator)

// Motor Command Output Register:
I502=$078104            ; Motor #5 Output command register for step and direction
I602=$07810C            ; Motor #6 Output command register for step and direction
I702=$078114            ; Motor #7 Output command register for step and direction
I802=$07811C            ; Motor #8 Output command register for step and direction
```

The position-Loop PID Gains can be calculated using the following equations:

$$Ixx30 = \left(\frac{660000}{Ixx08 \times PFMClock_{KHz}}\right)$$

$$Ixx31 = 0$$

$$Ixx32 = 6660 \times ServoFreq_{KHz}$$

$$Ixx33..Ixx35 = 0$$

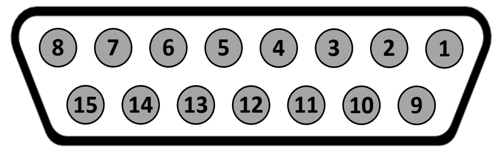
```
// Position-Loop PID Gains:
I530,4,100=11190      ; Motors 5-8 Proportional Gain
I531,4,100=0          ; Motors 5-8 Derivative Gain
I532,4,100=15038      ; Motors 5-8 Velocity FeedForward Gain
I533,4,100=0          ; Motors 5-8 Integral Gain
I534,4,100=0          ; Motors 5-8 Integral Mode
I535,4,100=0          ; Motors 5-8 Acceleration FeedForward Gain
```

Testing the PFM Output (using example settings):

Command Output	Mxx07 (Ixx69)	PFM [KHz]
0%	0	0
50%	1213	11
100%	2427	22

The corresponding channel can be commanded using either closed loop (#nJ+) or open loop (#nO10) commands. It is also possible to write directly to the output register (the channel has to be deactivated Ixx00=0 in this mode) using the suggested M-variable Mxx07.

X1-X8: Encoder Feedback, Sinusoidal



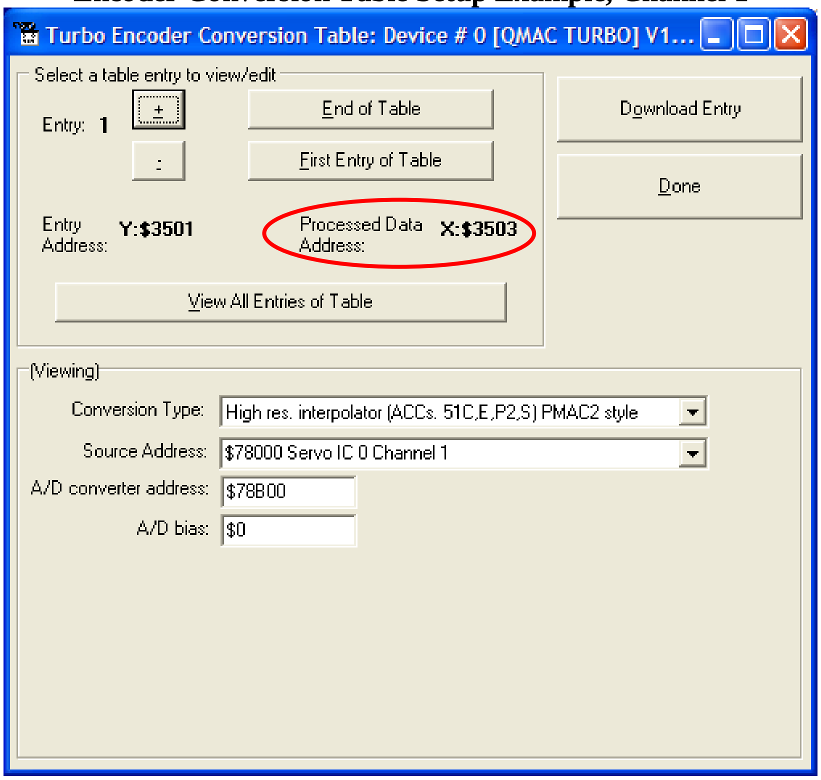
X1-X8: D-sub DA-15F Mating: D-sub DA-15M			
Pin #	**Symbol**	**Function**	**Notes**
1	Sin+	Input	Sine+
2	Cos+	Input	Cosine+
3	CHC+	Input	Index+
4	EncPwr	Output	Encoder Power 5 Volts
5	CHU+	In/Out	U Hall
6	CHW+	In/Out	W Hall
7	2.5 Volts	Output	Reference Power 2.5 volts
8			Unused
9	Sin-	Input	Sine-
10	Cos-	Input	Cosine-
11	CHC-	Input	Index-
12	GND	Common	Common Ground
13	CHV+	In/Out	V Hall
14	CHT+	In/Out	T Hall
15			Unused

This option allows the Geo Brick Drive to interface directly to up to eight sinusoidal feedback devices. The high resolution interpolator circuitry accepts inputs from sinusoidal or quasi-sinusoidal encoders (1-Volt peak to peak) and provides encoder position data. It creates 4,096 steps per sine-wave cycle.

Setting Up Sinusoidal Encoders

The Sinusoidal position feedback is set up through the Encoder Conversion Table (ECT) as a high resolution interpolation entry.

Encoder Conversion Table Setup Example, Channel 1



1. Conversion Type: High res. interpolator, PMAC2 Style
2. Enter Source Address (see table below)
3. Enter A/D Converter Address (see table below)
4. A/D Bias: always zero

Channel #	Source Address	A/D converter Address
1	$78000	$78B00
2	$78008	$78B02
3	$78010	$78B04
4	$78018	$78B06

Channel #	Source Address	A/D converter Address
5	$78100	$78B08
6	$78108	$78B0A
7	$78110	$78B0C
8	$78118	$78B0E

Note

Results are found in the processed data address, which the position and velocity feedback pointers (Ixx03, Ixx04) are usually assigned to.

The equivalent Turbo PMAC script code for 8-channel entries

```
// Channel 1
I8000=$FF8000  ; High resolution interpolator
I8001=$078B00  ; A/D converter address
I8002=$000000  ; Bias Term and Entry result
// Channel 2
I8003=$FF8008  ; High resolution interpolator
I8004=$078B02  ; A/D converter address
I8005=$000000  ; Bias Term and Entry result
// Channel 3
I8006=$FF8010  ; High resolution interpolator
I8007=$078B04  ; A/D converter address
I8008=$000000  ; Bias Term and Entry result
// Channel 4
I8009=$FF8018  ; High resolution interpolator
I8010=$078B06  ; A/D converter address
I8011=$000000  ; Bias Term and Entry result
// Channel 5
I8012=$FF8100  ; High resolution interpolator
I8013=$078B08  ; A/D converter address
I8014=$000000  ; Bias Term and Entry result
// Channel 6
I8015=$FF8108  ; High resolution interpolator
I8016=$078B0A  ; A/D converter address
I8017=$000000  ; Bias Term and Entry result
// Channel 7
I8018=$FF8110  ; High resolution interpolator
I8019=$078B0C  ; A/D converter address
I8020=$000000  ; Bias Term and Entry result
// Channel 8
I8021=$FF8118  ; High resolution interpolator
I8022=$078B0E  ; A/D converter address
I8023=$000000  ; Bias Term and Entry result
```

Position and Velocity feedback pointers should now be set to the corresponding ECT result:

```
I103=$3503 I104=$3503
I203=$3506 I204=$3506
I303=$3509 I304=$3509
I403=$350C I404=$350C
I503=$350F I504=$350F
I603=$3512 I604=$3512
I703=$3515 I704=$3515
I803=$3518 I804=$3518
```

Note

At this point of the setup, you should be able to move the motor/encoder shaft by hand and see ‘motor’ counts in the position window.

Counts Per User Units

With the interpolation of x 4096 in Turbo PMAC, there are 128 (4096/32) motor counts per sine/cosine cycles. Motor counts can be monitored in the motor position window upon moving the motor by hand.
Examples:
A **1024 Sine/Cosine** periods per revolution of a rotary encoder produces 1024 x 128 = **131,072 cts/rev.**
A **20 µm** linear encoder resolution produces 128/0.02 = **6400 cts/mm.**

Encoder Count Error (Mxx18)

The Geo Brick Drive has an encoder count error detection feature. If both the A and B channels of the quadrature encoder change state at the decode circuitry (post-filter) in the same hardware sampling clock (SCLK) cycle, an unrecoverable error to the counter value will result (lost counts). Suggested M-Variable Mxx18 for this channel is then set and latched to 1 (until reset or cleared). The three most common root causes of this error:

- Real encoder hardware problem
- Trying to move the encoder (motor) faster than it's specification
- Using an extremely high resolution/speed encoder. This may require increasing the SCLK

The default sampling clock in the Geo Brick Drive is ~ 10MHz, which is acceptable for virtually all applications. A setting of I7mn3 of 2257 (from default of 2258) sets the sampling clock SCLK at about ~20MHz. It can be increased to up to ~40 MHz.

Note

No automatic action is taken by the Geo Brick Drive if the encoder count error bit is set.

Encoder Loss Detection, Sinusoidal

The Encoder Loss circuitry uses the internal differential quadrature counts. It monitors each quadrature pair with an exclusive-or XOR gate. In normal operation mode, the two quadrature signals are in opposite logical states – that is one high and one low – yielding a true output from the XOR gate.

Channel	Address
1	Y:$78807,0,1
2	Y:$78807,1,1
3	Y:$78807,2,1
4	Y:$78807,3,1

Channel	Address
5	Y:$78807,4,1
6	Y:$78807,5,1
7	Y:$78807,6,1
8	Y:$78807,7,1

Status Bit	Definition
=0	Encoder lost, Fault
=1	Encoder present, no Fault

Caution

Appropriate action (user-written plc) needs to be implemented when an encoder loss is encountered. To avoid a runaway, an immediate Kill of the motor/encoder in question is strongly advised.

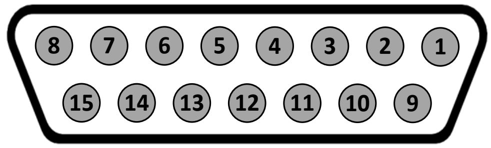
No automatic firmware (Geo Brick) action is taken upon detection of encoder(s) loss; it is the user's responsibility to perform the necessary action to make the application safe under these conditions, see example PLC below. Killing the motor/encoder in question is the safest action possible, and strongly recommended to avoid a runaway, and machine damage. Also, the user should decide the action to be taken (if any) for the other motors in the system. The Encoder Loss Status bit is a low true logic. It is set to 1 under normal conditions, and set to 0 when a fault (encoder loss) is encountered.

Encoder Loss Example PLC:

A 4-axis Geo Brick is setup to kill all motors upon detection of one or more encoder loss. In addition, it does not allow enabling any of the motors when an encoder is in a loss condition:

```
#define Mtr1AmpEna            M139   ; Motor#1 Amplifier Enable Status Bit
Mtr1AmpEna->X:$B0,19                 ; Suggested M-Variable
#define Mtr2AmpEna            M239   ; Motor#2 Amplifier Enable Status Bit
Mtr2AmpEna->X:$130,19                ; Suggested M-Variable
#define Mtr3AmpEna            M339   ; Motor#3 Amplifier Enable Status Bit
Mtr3AmpEna->X:$1B0,19                ; Suggested M-Variable
#define Mtr4AmpEna            M439   ; Motor#4 Amplifier Enable Status Bit
Mtr4AmpEna->X:$230,19                ; Suggested M-Variable
#define Mtr1EncLoss           M180   ; Motor#1 Encoder Loss Status Bit
Mtr1EncLoss->Y:$078807,0,1           ;
#define Mtr2EncLoss           M280   ; Motor#2 Encoder Loss Status Bit
Mtr2EncLoss->Y:$078807,1,1           ;
#define Mtr3EncLoss           M380   ; Motor#3 Encoder Loss Status Bit
Mtr3EncLoss->Y:$078807,2,1           ;
#define Mtr4EncLoss           M480   ; Motor#4 Encoder Loss Status Bit
Mtr4EncLoss->Y:$078807,3,1           ;
#define SysEncLoss            P1080  ; System Global Encoder Loss Status (user defined)
SysEncLoss=0                         ; Save and Set to 0 at download, normal operation
                                     ; =1 System Encoder Loss Occurred

OPEN PLC 1 CLEAR
If (SysEncLoss=0)      ; No Loss yet, normal mode
 If (Mtr1EncLoss=0 or Mtr2EncLoss=0 or Mtr4EncLoss=0 or Mtr4EncLoss=0)
  CMD^K                ; One or more Encoder Loss(es) detected, kill all motors
  SysEncLoss=1         ; Set Global Encoder Loss Status to Fault
 EndIf
EndIF
If (SysEncLoss=1)      ; Global Encoder Loss Status At Fault?
 If (Mtr1AmpEna=1 or Mtr2AmpEna=1 or Mtr4AmpEna=1 or Mtr4AmpEna=1) ; Trying to Enable Motors?
  CMD^K                ; Do not allow Enabling Motors, Kill all
 EndIF
EndIF
CLOSE
```

X1-X8: Encoder Feedback, Resolver

X1-X8: D-sub DA-15F **Mating: D-sub DA-15M**			
Pin #	**Symbol**	**Function**	**Notes**
1	Sin+	Input	Sine+
2	Cos+	Input	Cosine+
3	CHC+	Input	Index+
4	EncPwr	Output	Encoder Power 5 Volts
5			Unused
6			Unused
7	2.5 Volts	Output	Reference Power 2.5 volts
8			Unused
9	Sin-	Input	Sine-
10	Cos-	Input	Cosine-
11	CHC-	Input	Index-
12	GND	Common	Common Ground
13			Unused
14			Unused
15	ResOut	Output	Resolver Excitation Output

This option allows the Brick to connect to up to eight Resolver feedback devices.

Setting Up Resolvers

The Resolver data sampling is done at phase rate, and processed in the encoder conversion table. The commutation (occurring at phase rate) position is retrieved from the Encoder Conversion Table which is normally read at Servo rate. Thus, the Servo and Phase cycles have to be at the same rate.

Note

- Use an encoder cable with high quality shield. Connect the shield to chassis ground, and use ferrite core in noise sensitive environment if deemed necessary.
- It is essential to set the Servo clock the same as the Phase Clock in Resolver applications. This will greatly reduce noise.
- The Servo Cycle Extension Period (Ixx60) can be used to lower the CPU load and avoid quantization errors through the PID loop at high Servo rates.

Resolver Excitation Magnitude

Revolvers' excitation magnitude is a global setting used for all available Resolver channels. It has 15 possible settings:

```
#define ResExcMag M8000                ; Resolver Excitation Magnitude MACRO definition
ResExcMag->Y:$78B11,0,4                ; Resolver Excitation Magnitude register
```

Excitation Magnitude	Peak-Peak [Volts]
1	1.6
2	2.5
3	3.3
4	4.2
5	5.0
6	6.0
7	6.9
8	7.7

Excitation Magnitude	Peak-Peak [Volts]
9	8.5
10	9.5
11	10.4
12	11.3
13	12
14	13
15	14

Resolver Excitation Frequency

The Resolvers' excitation frequency is divided from the Phase clock and is setup to be the same as but not greater than the Resolvers' excitation frequency specification. The Resolver excitation frequency is a global setting used for all available Resolver channels, it has 4 possible settings:

```
#define ResExcFreq M8001       ; Resolver Excitation Frequency MACRO definition
ResExcFreq->Y:$78B13,0,4       ; Resolver Excitation Frequency register
```

Setting	Excitation Frequency
0	Phase Clock/1
1	Phase Clock/2
2	Phase Clock/4
3	Phase Clock/6

Note

The Resolver Excitation Magnitude and Frequency need to be executed once on power-up.

Resolver Data Registers

The Resolver raw data is found in the Resolver Data registers

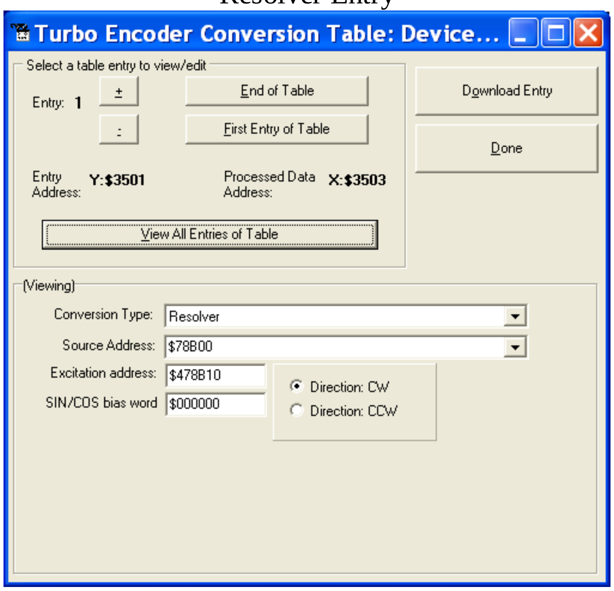
Channel	Register	Channel	Register
1	Y:$78B00	5	Y:$78B08
2	Y:$78B02	6	Y:$78B0A
3	Y:$78B04	7	Y:$78B0C
4	Y:$78B06	8	Y:$78B0E

Encoder Conversion Table Processing

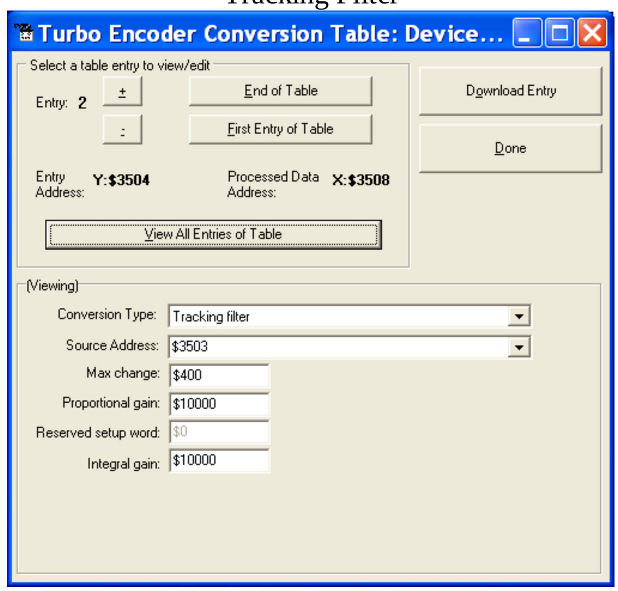
A dedicated 3-line Encoder Conversion Table entry is used for Resolver feedback.
Due to the noisy nature of Resolvers, implementing a tracking filter to the result is highly recommended. The Pewin32Pro2 software provides with an automatic encoder conversion table utility that can be used to implement both the Resolver entry and Tracking Filter. Under Configure>Encoder Conversion Table:

Channel 1 Resolver Setup Example

Resolver Entry



Tracking Filter



Steps:

1. Choose Resolver from Conversion Type pull-down menu.
2. Enter Source Address. See Resolver Data Registers table above.
3. Enter Excitation Address
   $4 Source address+$10
4. Download Entry.
5. Record Processed Data Address $3503 for channel 1.
6. Move up to the next Entry
7. Choose Tracking from Conversion Type pull-down menu.
8. Enter Source address. This is the result recorded in step5.
9. Download Entry
10. Record Processed Data Address. This is the source for position Ixx03 and velocity Ixx04 feedback pointers.

Calculating The Tracking Filter Gains

The tracking filter gains are system dependent, and need to be fine-tuned. This can be done by gathering and plotting filtered versus unfiltered data while moving the motor shaft manually. Best case scenario is super-imposing the filtered data on top of the unfiltered with minimum ripple and overshoot.

The empirical equations for the filter's proportional and integral gains (usually acceptable most applications) present a good starting point:

F_f: Filter Frequency (Hz)
S_f: Servo Frequency (Hz)

$$\text{Proportional Gain} = (F_f \times 2\pi)^2 \times \left(\frac{1}{S_f}\right)^2 \times 2^{23}$$

$$\text{Integral Gain} = (0.707 \times 2 \times F_f \times 2\pi) \times \left(\frac{1}{S_f}\right)^2 \times 2^{23}$$

Motors 1-8 Resolver Encoder Conversion Table Setup Example

```
// Channel 1
I8000= $F78B00 ; Resolver Counter Clockwise
I8001= $478B10 ; Excitation address
I8002= $000000 ; SIN/COS Bias word
I8003=$D83503  ; Tracking filter from conversion location $3503
I8004=$400     ; Maximum change in counts/cycle
I8005=$80000   ; Proportional gain
I8006=$0       ; Reserved setup word
I8007=$1       ; Integral gain
// Channel 2
I8008=$F78B02  ; Resolver Counter Clockwise
I8009=$478B10  ; Excitation address
I8010=$000000  ; SIN/COS Bias word
I8011=$D8350B  ; Tracking filter from conversion location $350B
I8012=$400     ; Maximum change in counts/cycle
I8013=$80000   ; Proportional gain
I8014=$0       ; Reserved setup word
I8015=$1       ; Integral gain
// Channel 3
I8016=$F78B04  ; Resolver Counter Clockwise
I8017=$478B10  ; Excitation address
I8018=$000000  ; SIN/COS Bias word
I8019=$D83513  ; Tracking filter from conversion location $3513
I8020=$400     ; Maximum change in counts/cycle
I8021=$80000   ; Proportional gain
I8022=$0       ; Reserved setup word
I8023=$1       ; Integral gain
// Channel 4
I8024=$F78B06  ; Resolver Counter Clockwise
I8025=$478B10  ; Excitation address
I8026=$000000  ; SIN/COS Bias word
I8027=$D8351B  ; Tracking filter from conversion location $351B
I8028=$400     ; Maximum change in counts/cycle
I8029=$80000   ; Proportional gain
I8030=$0       ; Reserved setup word
I8031=$1       ; Integral gain
// Channel 5
I8032=$F78B08  ; Resolver Counter Clockwise
I8033=$478B10  ; Excitation address
I8034=$000000  ; SIN/COS Bias word
I8035=$D83523  ; Tracking filter from conversion location $3523
I8036=$400     ; Maximum change in counts/cycle
I8037=$80000   ; Proportional gain
I8038=$0       ; Reserved setup word
I8039=$1       ; Integral gain
// Channel 6
I8040=$F78B0A  ; Resolver Counter Clockwise
I8041=$478B10  ; Excitation address
```

```
I8042=$000000  ; SIN/COS Bias word
I8043=$D8352B  ; Tracking filter from conversion location $352B
I8044=$400     ; Maximum change in counts/cycle
I8045=$80000   ; Proportional gain
I8046=$0       ; Reserved setup word
I8047=$1       ; Integral gain
// Channel 7
I8048=$F78B0C  ; Resolver Counter Clockwise
I8049=$478B10  ; Excitation address
I8050=$000000  ; SIN/COS Bias word
I8051=$D83533  ; Tracking filter from conversion location $3533
I8052=$400     ; Maximum change in counts/cycle
I8053=$80000   ; Proportional gain
I8054=$0       ; Reserved setup word
I8055=$1       ; Integral gain
// Channel 8
I8056=$F78B0E  ; Resolver Counter Clockwise
I8057=$478B10  ; Excitation address
I8058=$000000  ; SIN/COS Bias word
I8059=$D8353B  ; Tracking filter from conversion location $353B
I8060=$400     ; Maximum change in counts/cycle
I8061=$80000   ; Proportional gain
I8062=$0       ; Reserved setup word
I8063=$1       ; Integral gain
// End Of Table
I8064=$000000  ; End Of Table
```

Position, Velocity Feedback Pointers

```
I103=$3508     I104=$3508
I203=$3510     I204=$3510
I303=$3518     I304=$3518
I403=$3520     I404=$3520
I503=$3528     I504=$3528
I603=$3530     I604=$3530
I703=$3538     I704=$3538
I803=$3540     I804=$3540
```

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window.

Resolver Power-On PLC Example

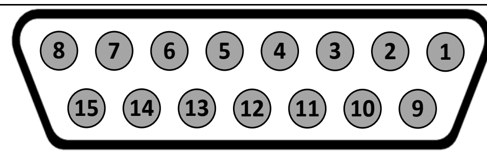
Setting up a resolver with 10V excitation magnitude and 10 KHz excitation frequency:

```
// Clock Settings: 10KHz Phase & Servo
I7100=5895     ; Servo IC1
I7101=0
I7102=0
I6800=5895     ; MACRO IC0
I6801=0
I6802=0
I7000=5895     ; Servo IC0
I7001=0
I7002=0
I10=838613     ; Servo Time Interrupt

#define ResExcMag  M8000      ; Excitation Magnitude
#define ResExcFreq M8001      ; Excitation Frequency
ResExcMag->Y:$78B11,0,4       ; Excitation Magnitude register
ResExcFreq->Y:$78B13,0,4      ; Excitation Frequency register
ResExcMag=11                  ;~10 Volts -User Input
ResExcFreq=0                  ; = Phase Clock/1 =10 KHz -User Input

// PLC to establish Resolver Magnitude & Frequency on power-up
Open plc 1 clear
ResExcMag=11
ResExcFreq=0
Disable plc 1
Close
```

X1-X8: Encoder Feedback, HiperFace

Caution

The majority of HiperFace devices requires 7-12VDC power. This has to be supplied externally and NOT wired into the brick unit. Pins#4 and #12 are unused in this case, leave floating.

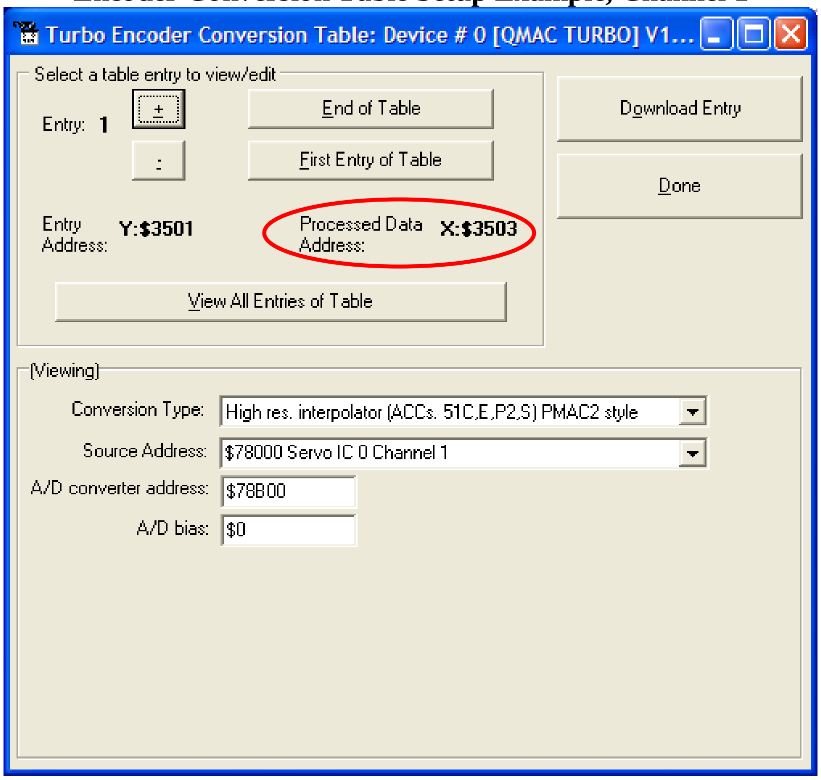
X1-X8: D-sub DA-15F Mating: D-Sub DA-15M			
Pin #	**Symbol**	**Function**	**Notes**
1	Sin+	Input	Sine+ signal input
2	Cos+	Input	Cosine+ signal input
3			Unused
4	EncPwr	Output	+5V encoder power
5	RS485-	Input	Data- Packet
6			Unused
7			Unused
8			Unused
9	SIN-		Sine- signal input
10	COS-		Cosine- signal input
11			Unused
12	GND	Common	Common ground
13			Unused
14	RS485+	Input	Data+ Packet
15			Unused

This option allows the Brick to connect to up to eight HiperFace type feedback devices.
The HiperFace on-going position (sinusoidal data) is processed by the x 4096 interpolator. The encoder conversion table is setup as a high resolution interpolator 3-line entry similarly to setting up a sinusoidal encoder. The absolute power-on position (serial data) is computed directly from the raw HiperFace serial data registers. Subsequently, a power-on phase referencing routine can be implemented.

Setting Up HiperFace On-Going Position

The HiperFace on-going position is set up through the Encoder Conversion Table as a high resolution interpolation entry

Encoder Conversion Table Setup Example, Channel 1



1. Conversion Type: High res. interpolator, PMAC2 Style
2. Enter Source Address (see table below)
3. Enter A/D Converter Address (see table below)
4. A/D Bias: typically =0

Channel #	Source Address	A/D converter Address
1	$78000	$78B00
2	$78008	$78B02
3	$78010	$78B04
4	$78018	$78B06

Channel #	Source Address	A/D converter Address
5	$78100	$78B08
6	$78108	$78B0A
7	$78110	$78B0C
8	$78118	$78B0E

Note

Results are found in the processed data address, which the position and velocity feedback pointers (Ixx03, Ixx04) are usually pointed to.

And the equivalent Turbo PMAC code for setting up all 8 channels:

```
// Channel 1
I8000=$FF8000  ; High resolution interpolator entry, $78000
I8001=$078B00  ; A/D converter address, $78B00
I8002=$000000  ; Bias Term and Entry result at $3503
// Channel 2
I8003=$FF8008  ; High resolution interpolator entry, $78008
I8004=$078B02  ; A/D converter address, $78B02
I8005=$000000  ; Bias Term and Entry result at $3506
// Channel 3
I8006=$FF8010  ; High resolution interpolator entry, $78010
I8007=$078B04  ; A/D converter address, $78B04
I8008=$000000  ; Bias Term and Entry result at $3509
// Channel 4
I8009=$FF8018  ; High resolution interpolator entry, $78018
I8010=$078B06  ; A/D converter address, $78B06
I8011=$000000  ; Bias Term and Entry result at $350C
// Channel 5
I8012=$FF8100  ; High resolution interpolator entry, $78100
I8013=$078B08  ; A/D converter address, $78B08
I8014=$000000  ; Bias Term and Entry result at $350F
// Channel 6
I8015=$FF8108  ; High resolution interpolator entry, $78108
I8016=$078B0A  ; A/D converter address, $78B0A
I8017=$000000  ; Bias Term and Entry result at $3512
// Channel 7
I8018=$FF8110  ; High resolution interpolator entry, $78110
I8019=$078B0C  ; A/D converter address, $78B0C
I8020=$000000  ; Bias Term and Entry result at $3515
// Channel 8
I8021=$FF8118  ; High resolution interpolator entry, $78118
I8022=$078B0E  ; A/D converter address, $78B0E
I8023=$000000  ; Bias Term and Entry result at $3518
```

Now, the position and velocity pointers are assigned to the corresponding processed data register:

```
I103=$3503 I104=$3503  ; Motor #1 Position and Velocity feedback address
I203=$3506 I204=$3506  ; Motor #2 Position and Velocity feedback address
I303=$3509 I304=$3509  ; Motor #3 Position and Velocity feedback address
I403=$350C I404=$350C  ; Motor #4 Position and Velocity feedback address
I503=$350F I504=$350F  ; Motor #5 Position and Velocity feedback address
I603=$3512 I604=$3512  ; Motor #6 Position and Velocity feedback address
I703=$3515 I704=$3515  ; Motor #7 Position and Velocity feedback address
I803=$3518 I804=$3518  ; Motor #8 Position and Velocity feedback address
```

Channel Activation

```
I100,8,100=1           ; Motors 1-8 activated
```

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window.

Counts Per Revolution:

With the interpolation of x 4096 in Turbo PMAC, there are 128 (4096/32) motor counts per sine/cosine cycles. Motor counts can be monitored in the motor position window upon moving the motor by hand.

Examples:

A **1024 Sine/Cosine** periods per revolution rotary encoder produces 1024 x 128 = **131,072 cts/rev.**

A **20 µm** resolution linear encoder produces 128/0.02 = **6400 cts/mm.**

Setting Up HiperFace Absolute Power-On Position

Setting up the absolute position read with HiperFace requires the programming of two essential control registers:

- Global Control Registers
- Channel Control Registers

The resulting data is found in:

- HiperFace Data Registers

Global Control Registers

X:$78BnF (default value: $812004)   where n=2 for axes 1-4
n=3 for axes 5-8

	Global Control Register
Axes 1-4	X:$78B2F
Axes 5-8	X:$78B3F

The Global Control register is used to program the serial encoder interface clock frequency *SER_Clock* and configure the serial encoder interface trigger clock. *SER_Clock* is generated from a two-stage divider clocked at 100 MHz as follows:

$$\text{Ser\_Clock} = \frac{100}{(M+1) \times 2^N} \quad \text{MHz}$$

$$\text{Baud Rate} = \frac{\text{Ser\_Clock}}{20}$$

M	N	SER_Clock [KHz]	Baud Rate	Global Register Setting
129	2	192.30	9600	$812004
129	3	96.15	4800	$813004
129	1	394.61	19200	$812004

Default Settings: M=129, N=2

There are two external trigger sources; phase and servo. Bits [9:8] in the Global Control register are used to select the source and active edge to use as the internal serial encoder trigger. The internal trigger is used by all four channels to initiate communication with the encoder. To compensate for external system delays, this trigger has a programmable 4-bit delay setting in 20 µsec increments.

23--16	15--12	11	10	9	8	7	6	5	4	3	2	1	0
M_Divisor	N_Divisor			Trigger Clock	Trigger Edge	Trigger Delay				Protocol Code			

Bit	**Type**	**Default**	**Name**	**Description**
[23:16]	R/W	0x81	M_Divisor	Intermediate clock frequency for *SER_Clock*. The intermediate clock is generated from a (M+1) divider clocked at 100 MHz.
[15:12]	R/W	0x2	N_Divisor	Final clock frequency for *SER_Clock*. The final clock is generated from a 2^N divider clocked by the intermediate clock.
[11:10]	R	00	Reserved	Reserved and always reads zero.
[09]	R/W	0	TriggerClock	Trigger clock select = 0 Phase Clock = 1 Servo Clock
[08]	R/W	0	TriggerEdge	Active clock edge select = 0 Rising edge = 1 Falling edge
[07:04]	R/W	0x0	TriggerDelay	Trigger delay program relative to the active edge of the trigger clock. Units are in increments of 20 usec.
[03:00]	R	0x4	ProtocolCode	This read-only bit field is used to read the serial encoder interface protocol supported by the FPGA. A value of **$4** defines this protocol as **HiperFace**.

Channel Control Registers

X:$78Bn0, X:$78Bn4, X:$78Bn8, X:$78BnC where: n=2 for axes 1-4
n=3 for axes 5-8

Channel 1	X:$78B20	**Channel 5**	X:$78B30
Channel 2	X:$78B24	**Channel 6**	X:$78B34
Channel 3	X:$78B28	**Channel 7**	X:$78B38
Channel 4	X:$78B2C	**Channel 8**	X:$78B3C

Each channel has its own Serial Encoder Command Control Register defining functionality parameters. Parameters such as setting the number of position bits in the serial bit stream, enabling/disabling channels through the *SENC_MODE* **(**when this bit is cleared, the serial encoder pins of that channel are tri-stated), enabling/disabling communication with the encoder using the trigger control bit. An 8-bit mode command is required for encoder communication. Currently, three HiperFace commands are supported; read encoder position ($42), read encoder status ($50) and Reset encoder($53).

[23:16]	[15:14]	13	12	11	10	[9:8]	[7:0]
Command Code		Trigger Mode	Trigger Enable		Rxdataready SencMode		Encoder Address

Bit	Type	Default	Name	Description
[23:16]	W	0x42	Command Code	$42 – Read Encoder Position $50 – Read Encoder Status $53 – Reset Encoder
[15:14]		0	Reserved	Reserved and always reads zero.
[13]	R/W	0	Trigger Mode	Trigger Mode to initiate communication: 0= continuous trigger 1= one-shot trigger - for HiperFace All triggers occur at the defined Phase/Servo clock edge and delay setting. Due to HiperFace protocol speed limitation, only one-shot trigger mode is used.
[12]	R/W	1	Trigger Enable	0= disabled 1= enabled This bit must be set for either trigger mode. If the Trigger Mode bit is set for one-shot mode, the hardware will automatically clear this bit after the trigger occurs.
[11]		0	Reserved	Reserved and always reads zero.
[10]	R	0	RxData Ready	This read-only bit provides the received data status. It is low while the interface logic is communicating (busy) with the serial encoder. It is high when all the data has been received and processed.
	W	1	SENC_MODE	This write-only bit is used to enable the output drivers for the SENC_SDO, SENC_CLK, SENC_ENA pins for each respective channel.
[09:08]		0x00	Reserved	Reserved and always reads zero.
[07:00]	R/W	0xFF	Encoder address	This bit field is normally used to define the encoder address transmitted with each command. Delta Tau does not support multiple encoders per channel; a value of $FF sends a general broadcast.

HiperFace Data Registers

The HiperFace absolute power-on data is conveyed into 4 memory locations; Serial Encoder Data A, B, C, and D.

The Serial Encoder Data A register holds the 24 bits of the encoder position data. If the data exceeds the 24 available bits in this register, the upper overflow bits are LSB justified and readable in the Serial Encoder Data B, which also holds status and error bits. Serial Encoder Data C, and D registers are reserved and always read zero.

HiperFace Data B						**HiperFace Data A**
23	22	21	20	[19:16]	[07:0]	[23:0]
TimeOut Error	CheckSum Error	Parity Error	Error Bit		Position Data [31:24]	Position Data [23:0]

	HiperFace Serial Data A	**HiperFace Serial Data B**
Channel 1	Y:$78B20	Y:$78B21
Channel 2	Y:$78B24	Y:$78B25
Channel 3	Y:$78B28	Y:$78B29
Channel 4	Y:$78B2C	Y:$78B2D
Channel 5	Y:$78B30	Y:$78B31
Channel 6	Y:$78B34	Y:$78B35
Channel 7	Y:$78B38	Y:$78B39
Channel 8	Y:$78B3C	Y:$78B3D

Data Registers C and D are listed here for future use and documentation purposes only. They do not pertain to the HiperFace setup and always read zero.

	HiperFace Serial Data C	**HiperFace Serial Data D**
Channel 1	Y:$78B22	Y:$78B23
Channel 2	Y:$78B26	Y:$78B27
Channel 3	Y:$78B2A	Y:$78B28
Channel 4	Y:$78B2E	Y:$78B2F
Channel 5	Y:$78B32	Y:$78B33
Channel 6	Y:$78B36	Y:$78B37
Channel 7	Y:$78B3A	Y:$78B38
Channel 8	Y:$78B3E	Y:$78B3F

Setting Up HiperFace Encoders Example

An 8-axis Geo Brick Drive is connected to eight HiperFace encoders, serial data is programmed to 9600 (M=129, N=2) baud rate for all eight channels:

$$\text{Ser\_Clock} = \frac{100}{(M+1) \times 2^N} \text{ MHz}$$

$$\text{Baud Rate} = \frac{\text{Ser\_Clock}}{20}$$

=0 Rising Edge
=1 Falling Edge

=0 Trigger on Phase
=1 Trigger on Servo

Typically =0

$4 for HiperFace

Description:	M Divisor								N Divisor				0	0	clock	Edge	Trigger Delay				Protocol			
Bit #:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Hex ($):	**8**				**1**				**2**				**0**				**0**				**4**			

The only user configurable HiperFace Global Control field is the baud rate (M and N divisors).

Note

The channel control registers are programmed to read position ($42):

= $42 Read position
= $50 Encoder Status
= $53 Reset Encoder

=0 Continuous
=1 One shot

=0 Disabled
=1 Enabled

=0 Disabled
=1 Enabled

Always $FF for General Broadcast

Description:	Command code								0	0	Trigger Mode	Trigger Enable	0	Senc Mode	0	0	Encoder Address							
Bit #:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	1	0	0	0	0	1	0	0	0	1	1	0	1	0	0	1	1	1	1	1	1	1	1
Hex ($):	**4**				**2**				**3**				**4**				**F**				**F**			

The only user configurable HiperFace Channel Control field is the command code:
$42 to read position
$50 to read encoder status
$53 to reset encoder

Note

The Global and Channel Control registers have to be initialized on power-up. Following, is an example PLC showing the initialization of all eight channels:

```
//=========================== NOTES ABOUT THIS PLC EXAMPLE ================================//
// This PLC example utilizes: - M5990 through M5999
//                            - Coordinate system 1 Timer 1
// Make sure that current and/or future configurations do not create conflicts with
// these parameters.
//=======================================================================================//

M5990..5999->* ; Self-referenced M-Variables
M5990..5999=0  ; Reset at download

//========================= GLOBAL CONTROL REGISTERS =====================================//
#define HFGlobalCtrl1_4       M5990   ; Channels 1-4 HiperFace global control register
#define HFGlobalCtrl5_8       M5991   ; Channels 5-8 HiperFace global control register
HFGlobalCtrl1_4->X:$78B2F,0,24,U      ; Channels 1-4 HiperFace global control register address
HFGlobalCtrl5_8->X:$78B3F,0,24,U      ; Channels 5-8 HiperFace global control register address

//======================== CHANNEL CONTROL REGISTERS =====================================//
#define Ch1HFCtrl             M5992   ; Channel 1 HiperFace control register
#define Ch2HFCtrl             M5993   ; Channel 2 HiperFace control register
#define Ch3HFCtrl             M5994   ; Channel 3 HiperFace control register
#define Ch4HFCtrl             M5995   ; Channel 4 HiperFace control register
#define Ch5HFCtrl             M5996   ; Channel 5 HiperFace control register
#define Ch6HFCtrl             M5997   ; Channel 6 HiperFace control register
#define Ch7HFCtrl             M5998   ; Channel 7 HiperFace control register
#define Ch8HFCtrl             M5999   ; Channel 8 HiperFace control register

Ch1HFCtrl->X:$78B20,0,24,U ; Channel 1 HiperFace control register Address
Ch2HFCtrl->X:$78B24,0,24,U ; Channel 2 HiperFace control register Address
Ch3HFCtrl->X:$78B28,0,24,U ; Channel 3 HiperFace control register Address
Ch4HFCtrl->X:$78B2C,0,24,U ; Channel 4 HiperFace control register Address
Ch5HFCtrl->X:$78B30,0,24,U ; Channel 5 HiperFace control register Address
Ch6HFCtrl->X:$78B34,0,24,U ; Channel 6 HiperFace control register Address
Ch7HFCtrl->X:$78B38,0,24,U ; Channel 7 HiperFace control register Address
Ch8HFCtrl->X:$78B3C,0,24,U ; Channel 8 HiperFace control register Address

//========= POWER-ON PLC EXAMPLE, GLOBAL & CHANNEL CONTROL REGISTERS ======================//
Open PLC 1 Clear
HFGlobalCtrl1_4=$812004       ; Channels 1-4 HiperFace, 9600 baud rate (M=129 N=2) -User Input
HFGlobalCtrl5_8=$812004       ; Channels 5-8 HiperFace, 9600 baud rate (M=129 N=2) -User Input

Ch1HFCtrl=$4234FF      ; Channel 1 HiperFace control register (read position) -User Input
Ch2HFCtrl=$4234FF      ; Channel 2 HiperFace control register (read position) -User Input
Ch3HFCtrl=$4234FF      ; Channel 3 HiperFace control register (read position) -User Input
Ch4HFCtrl=$4234FF      ; Channel 4 HiperFace control register (read position) -User Input
Ch5HFCtrl=$4234FF      ; Channel 5 HiperFace control register (read position) -User Input
Ch6HFCtrl=$4234FF      ; Channel 6 HiperFace control register (read position) -User Input
Ch7HFCtrl=$4234FF      ; Channel 7 HiperFace control register (read position) -User Input
Ch8HFCtrl=$4234FF      ; Channel 8 HiperFace control register (read position) -User Input
I5111=500*8388608/I10 while(I5111>0) endw    ; ½ sec delay
Dis plc 1              ; Execute once on power-up or reset
Close
//=======================================================================================//
```

Channels 1 through 4 are driving HiperFace encoders with **12-bit** (4096) **single-turn** resolution and **12-bit** (4096) **multi-turn** resolution for a total number of data bits of 24 (12+12). The entire data stream is held in the HiperFace serial data A register:

HiperFace Data A Register	**HiperFace Data A Register**	
[23:0]	[23:0]	[11:0]
	Multi-Turn Data	Single-Turn Data

Channels 5 through 8 are driving HiperFace encoders with **16-bit** (65536) **single-turn** resolution and **12-bit** (4096) **multi-turn** resolution for a total number of data bits of 28 (16+12). The HiperFace serial Data A register holds the 16-bit single-turn data and the first 8 bits of multi-turn data. The Hiperface serial Data B register holds the 4 bits overflow of multi-turn data:

HiperFace Data B Register		**HiperFace Data A Register**	
[23:4]	[3:0]	[23:15]	[15:0]
	Multi-Turn Data1	Multi-Turn Data	Single-Turn Data

The automatic absolute position read in PMAC, using Ixx10 and Ixx95, expects the data to be left shifted (5-bits) in the Encoder Conversion Table. Reading raw data and constructing position directly out of the serial encoder registers requires a custom procedure.

The following example PLC reads and constructs the absolute position for channels 1 through 8. It is pre-configured for the user to input their encoder information, and specify which channels are being used.

Using The Absolute Position Read Example PLC
Under User Input section:

1. Enter single turn (Ch**x**STRes) and multi turn (Ch**x**MTRes) resolutions in bits for each encoder. For strictly absolute single turn encoders, multi turn resolution is set to zero.
2. In ChAbsSel, specify which channels are desired to perform an absolute position read. This value is in hexadecimal. A value of 1 specifies that this channel is connected, 0 specifies that it is not connected and should not perform and absolute read. Examples:

Reading Absolute Position, channels 1 through 4

Channel#	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
ChAbsSel (Binary)	0	0	0	0	1	1	1	1
ChAbsSel (Hex)	0				F			

=> **ChAbsSel=$0F**

Reading Absolute Position, channels 1,3,5,7

Channel#	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
ChAbsSel (Binary)	0	1	0	1	0	1	0	1
ChAbsSel (Hex)	5				5			

=> **ChAbsSel=$55**

```
//=========================== NOTES ABOUT THIS PLC EXAMPLE ================================//
// This PLC example utilizes: - M6000 through M6035
//                            - P7000 through P7032
// Make sure that current and/or future configurations do not create conflicts with
// these parameters.
//=========================================================================================//

M6000..6035->*         ; Self-referenced M-Variables
M6000..6035=0          ; Reset M-Variables at download
P7000..7032=0          ; Reset P-Variables at download
//===================================== USER INPUT ========================================//
#define Ch1STRes P7000        #define Ch1MTRes P7001
#define Ch2STRes P7002        #define Ch2MTRes P7003
#define Ch3STRes P7004        #define Ch3MTRes P7005
```

```
#define Ch4STRes P7006        #define Ch4MTRes P7007
#define Ch5STRes P7008        #define Ch5MTRes P7009
#define Ch6STRes P7010        #define Ch6MTRes P7011
#define Ch7STRes P7012        #define Ch7MTRes P7013
#define Ch8STRes P7014        #define Ch8MTRes P7015

Ch1STRes=12  Ch1MTRes=12      ; Ch1 Multi Turn and Single Turn Resolutions --User Input
Ch2STRes=12  Ch2MTRes=12      ; Ch2 Multi Turn and Single Turn Resolutions --User Input
Ch3STRes=12  Ch3MTRes=12      ; Ch3 Multi Turn and Single Turn Resolutions --User Input
Ch4STRes=12  Ch4MTRes=12      ; Ch4 Multi Turn and Single Turn Resolutions --User Input
Ch5STRes=16  Ch5MTRes=12      ; Ch5 Multi Turn and Single Turn Resolutions --User Input
Ch6STRes=16  Ch6MTRes=12      ; Ch6 Multi Turn and Single Turn Resolutions --User Input
Ch7STRes=16  Ch7MTRes=12      ; Ch7 Multi Turn and Single Turn Resolutions --User Input
Ch8STRes=16  Ch8MTRes=12      ; Ch8 Multi Turn and Single Turn Resolutions --User Input

#define ChAbsSel       P7016  ; Select Channels using absolute read (in Hexadecimal)
ChAbsSel=$FF                  ; Channels selected for absolute position read –User Input

//================================ DEFINITIONS & SUBSTITUTIONS =============================//
#define SerialRegA     M6000  ; HiperFace Serial Data Register A
#define SerialRegB     M6001  ; HiperFace Serial Data Register B
#define Two2STDec      M6002  ; 2^STRes in decimal, for shifting operations
#define Two2STHex      M6003  ; 2^STRes in Hexadecimal, for bitwise operations
#define Two2MTDec      M6004  ; 2^MTRes in decimal, for shifting operations
#define Two2MTHex      M6005  ; 2^MTRes in Hexadecimal, for bitwise operations
#define MTTemp1        M6006  ; Multi Turn Data temporary holding register 1
#define MTTemp2        M6007  ; Multi Turn Data temporary holding register 2
#define STTemp1        M6008  ; Single Turn Data temporary holding register 1
#define STTemp2        M6009  ; Single Turn Data temporary holding register 2
#define ChNoHex        M6010  ; Channel Number in Hex
#define ChAbsCalc      M6011  ; Abs. calc. flag (=1 true do read, =0 false do not do read)
#define LowerSTBits    P7017  ; Lower Single Turn Bits, RegA
#define UpperSTBits    P7018  ; Upper Single Turn Bits, RegB (where applicable)
#define LowerMTBits    P7019  ; Lower Multi Turn Bits, RegA (where applicable)
#define UpperMTBits    P7020  ; Upper Multi Turn Bits, RegB (where applicable)
#define STData         P7021  ; Single Turn Data Word
#define MTData         P7022  ; Multi Turn Data Word
#define NegTh          P7023  ; Negative Threshold
#define Temp1          P7024  ; General Temporary holding register 1
#define Temp2          P7025  ; General Temporary holding register 2
#define SerialBase     P7026  ; Indirect addressing index for serial registers, 6020
#define ChBase         P7027  ; Indirect addressing index for channel No, 162
#define ChNo           P7028  ; Current Channel Number
#define ResBase        P7029  ; Indirect Addressing index for resolution input, 6000
#define STRes          P7030  ; Single Turn Resolution of currently addressed channel
#define MTRes          P7031  ; Multi Turn Resoltuion of currently addressed channel
#define PsfBase        P7032  ; Indirect addressing for position scale factor Ixx08, 108
// HiperFace Serial Data Registers A and B
M6020->Y:$78B20,0,24,U        M6021->Y:$78B21,0,24,U        ; Channel 1
M6022->Y:$78B24,0,24,U        M6023->Y:$78B25,0,24,U        ; Channel 2
M6024->Y:$78B28,0,24,U        M6025->Y:$78B29,0,24,U        ; Channel 3
M6026->Y:$78B2C,0,24,U        M6027->Y:$78B2D,0,24,U        ; Channel 4
M6028->Y:$78B30,0,24,U        M6029->Y:$78B31,0,24,U        ; Channel 5
M6030->Y:$78B34,0,24,U        M6031->Y:$78B35,0,24,U        ; Channel 6
M6032->Y:$78B38,0,24,U        M6033->Y:$78B39,0,24,U        ; Channel 7
M6034->Y:$78B3C,0,24,U        M6035->Y:$78B3D,0,24,U        ; Channel 8

//===================================== PLC SCRIPT ========================================//
Open PLC 1 Clear
ChNo=0
While(ChNo!>7) ; Loop for 8 Channels
 ChNo=ChNo+1
 ChNoHex=exp((ChNo-1)*ln(2))
 ChAbsCalc=(ChAbsSel&ChNoHex)/ChNoHex
 If (ChAbsCalc!=0)     ; Absolute read on this channel?
  SerialBase=6020+(ChNo-1)*2
  SerialRegA=M(SerialBase)
  SerialRegB=M(SerialBase+1)
  ResBase=7000+(ChNo-1)*2
  STRes=P(ResBase)
  MTRes=P(ResBase+1)
```

```
  STData=0
  MTData=0
  If (STRes!>24) ; Single Turn Res<=24
   //===========SINGLE TURN DATA===========//
   Two2STDec=exp(STRes*ln(2))
   Two2STHex=Two2STDec-1
   STData=SerialRegA&Two2STHex
   //===========MULTI TURN DATA============//
   Two2MTDec=exp(MTRes*ln(2))
   Two2MTHex=Two2MTDec-1
   If (MTRes=0)
    LowerMTBits=0
    UpperMTBits=0
    Two2MTDec=0
    Two2MTHex=0
    MTData=0
   Else
    LowerMTBits=24-STRes
    STTemp1=exp(LowerMTBits*ln(2))
    STTemp2=0
    UpperMTBits=MTRes-LowerMTBits
    MTTemp1=exp(LowerMTBits*ln(2))
    MTTemp2=exp(UpperMTBits*ln(2))
    Temp1=(SerialRegA/Two2STDec)&(MTTemp1-1)
    Temp2=SerialRegB&(MTTemp2-1)
    MTData=Temp2*STTemp1+Temp1
   EndIf
   Else ; Single Turn Res>24
    //===========SINGLE TURN DATA===========//
    LowerSTBits=24
    UpperSTBits=STRes-24
    STTemp1=exp(UpperSTBits*ln(2))
    STTemp2=STTemp1-1
    Two2STDec=16777216*STTemp1
    Two2STHex=Two2STDec-1
    STData=(SerialRegB&STTemp2)*16777216+SerialRegA
    //===========MULTI TURN DATA============//
    If (MTRes=0)
     LowerMTBits=0
     UpperMTBits=0
     Two2MTDec=0
     Two2MTHex=0
     MTData=0
    Else
     Two2MTDec=exp(MTRes*ln(2))
     Two2MTHex=Two2MTDec-1
     LowerMTBits=0
     UpperMTBits=MTRes
     MTTemp1=exp(UpperMTBits*ln(2))
     MTTemp2=MTTemp1-1
     MTData=(SerialRegB/STTemp1)&MTTemp2
    EndIf
   EndIf
  //======ASSEMBLING ACTUAL POSITION======//
  ChBase=162+(ChNo-1)*100
  PsfBase=108+(ChNo-1)*100
  NegTh=Two2MTDec/2
  If (MTData!>NegTh)
   M(ChBase)=(MTData*Two2STDec+STData)*32*I(PsfBase)
  Else
   M(ChBase)=-(((Two2MTHex-MTData)*Two2STDec)+(Two2STDec-STData))*32*I(PsfBase)
  EndIf
 EndIf
EndW
ChNo=0
Dis plc 1
Close
```

Encoder Count Error (Mxx18)

The Geo Brick Drive has an encoder count error detection feature. If both the A and B channels of the quadrature encoder change state at the decode circuitry (post-filter) in the same hardware sampling clock (SCLK) cycle, an unrecoverable error to the counter value will result (lost counts). Suggested M-Variable Mxx18 for this channel is then set and latched to 1 (until reset or cleared). The three most common root causes of this error:

- Real encoder hardware problem
- Trying to move the encoder (motor) faster than it's specification
- Using an extremely high resolution/speed encoder. This may require increasing the SCLK

The default sampling clock in the Geo Brick Drive is ~ 10MHz, which is acceptable for virtually all applications. A setting of I7mn3 of 2257 (from default of 2258) sets the sampling clock SCLK at about ~20MHz. It can be increased to up to ~40 MHz.

Note

No automatic action is taken by the Geo Brick Drive if the encoder count error bit is set.

Encoder Loss Detection, HiperFace

The Encoder Loss circuitry uses the internal differential quadrature counts. It monitors each quadrature pair with an exclusive-or XOR gate. In normal operation mode, the two quadrature signals are in opposite logical states – that is one high and one low – yielding a true output from the XOR gate.

Channel	Address
1	Y:$78807,0,1
2	Y:$78807,1,1
3	Y:$78807,2,1
4	Y:$78807,3,1

Channel	Address
5	Y:$78807,4,1
6	Y:$78807,5,1
7	Y:$78807,6,1
8	Y:$78807,7,1

Status Bit	Definition
=0	Encoder lost, Fault
=1	Encoder present, no Fault

Caution

Appropriate action (user-written plc) needs to be implemented when an encoder loss is encountered. To avoid a runaway, an immediate Kill of the motor/encoder in question is strongly advised.

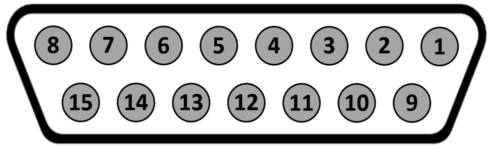
No automatic firmware (Geo Brick) action is taken upon detection of encoder(s) loss; it is the user's responsibility to perform the necessary action to make the application safe under these conditions, see example PLC below. Killing the motor/encoder in question is the safest action possible, and strongly recommended to avoid a runaway, and machine damage. Also, the user should decide the action to be taken for the other motors in the system. The Encoder Loss Status bit is a low true logic. It is set to 1 under normal conditions, and set to 0 when a fault (encoder loss) is encountered.

Encoder Loss Example PLC:

A 4-axis Geo Brick is setup to kill all motors upon detection of one or more encoder loss. In addition, it does not allow enabling any of the motors when an encoder is in a loss condition:

```
#define Mtr1AmpEna            M139    ; Motor#1 Amplifier Enable Status Bit
Mtr1AmpEna->X:$B0,19                  ; Suggested M-Variable
#define Mtr2AmpEna            M239    ; Motor#2 Amplifier Enable Status Bit
Mtr2AmpEna->X:$130,19                 ; Suggested M-Variable
#define Mtr3AmpEna            M339    ; Motor#3 Amplifier Enable Status Bit
Mtr3AmpEna->X:$1B0,19                 ; Suggested M-Variable
#define Mtr4AmpEna            M439    ; Motor#4 Amplifier Enable Status Bit
Mtr4AmpEna->X:$230,19                 ; Suggested M-Variable
#define Mtr1EncLoss           M180    ; Motor#1 Encoder Loss Status Bit
Mtr1EncLoss->Y:$078807,0,1            ;
#define Mtr2EncLoss           M280    ; Motor#2 Encoder Loss Status Bit
Mtr2EncLoss->Y:$078807,1,1            ;
#define Mtr3EncLoss           M380    ; Motor#3 Encoder Loss Status Bit
Mtr3EncLoss->Y:$078807,2,1            ;
#define Mtr4EncLoss           M480    ; Motor#4 Encoder Loss Status Bit
Mtr4EncLoss->Y:$078807,3,1            ;
#define SysEncLoss            P5989   ; System Global Encoder Loss Status (user defined)
SysEncLoss=0                          ; Save and Set to 0 at download, normal operation
                                      ; =1 System Encoder Loss Occurred

OPEN PLC 1 CLEAR
If (SysEncLoss=0)      ; No Loss yet, normal mode
 If (Mtr1EncLoss=0 or Mtr2EncLoss=0 or Mtr4EncLoss=0 or Mtr4EncLoss=0)
  CMD^K                ; One or more Encoder Loss(es) detected, kill all motors
  SysEncLoss=1         ; Set Global Encoder Loss Status to Fault
 EndIf
EndIF
If (SysEncLoss=1)      ; Global Encoder Loss Status At Fault?
 If (Mtr1AmpEna=1 or Mtr2AmpEna=1 or Mtr4AmpEna=1 or Mtr4AmpEna=1) ; Trying to Enable Motors?
  CMD^K                ; Do not allow Enabling Motors, Kill all
 EndIF
EndIF
CLOSE
```

X1-X8: Encoder Feedback, SSI

X1-X8: D-sub DA-15F **Mating: D-sub DA-15M**			
Pin #	**Symbol**	**Function**	**Notes**
1			Unused
2			Unused
3			Unused
4	EncPwr	Output	Encoder Power 5 Volts only
5	Data-	Input	Data- packet
6	Clock-	Output	Serial Encoder Clock-
7			Unused
8			Unused
9			Unused
10			Unused
11			Unused
12	GND	Common	Common Ground
13	Clock+	Output	Serial Encoder Clock+
14	Data+	Input	Data+ Packet
15			Unused

Note

- Some SSI devices require 24V power which has to be brought in externally. Pins #4, and #12 are unused in this case, leave floating.
- Hardware capture is not available with Serial Data encoders

Configuring SSI

Configuring the SSI protocol requires the programming of two essential control registers:

- Global Control Registers
- Channel Control Registers

The resulting data is found in:

- SSI Data Registers

Global Control Registers

X:$78BnF (Default value: $630002) where: n=2 for axes 1-4
n=3 for axes 5-8

	Global Control Register
Axes 1-4	X:$78B2F
Axes 5-8	X:$78B3F

The Global Control register is used to program the serial encoder interface clock frequency *SER_Clock* and configure the serial encoder interface trigger clock. *SER_Clock* is generated from a two-stage divider clocked at 100 MHz:

$$\text{Ser\_Clock} = \frac{100}{(M+1)\times 2^N} \quad \text{MHz}$$

M	N	Clock Frequency
49	0	2.0 MHz
99	0	1.0 MHz
99	1	500.0 KHz
99	2	250.0 KHz
…	…	

Default Settings: M=99, N=0 => 1 MHz transfer rates

There are two external trigger sources; phase and servo. Bits [9:8] in the Global Control register are used to select the source and active edge to use as the internal serial encoder trigger. The internal trigger is used by all four channels to initiate communication with the encoder. To compensate for external system delays, this trigger has a programmable 4-bit delay setting in 20 µsec increments.

23--16	15--12	11	10	9	8	7	6	5	4	3	2	1	0
M_Divisor	N_Divisor			Trigger Clock	Trigger Edge	Trigger Delay				Protocol Code			

Bit	Type	Default	Name	Description
[23:16]	R/W	0x63	M_Divisor	Intermediate clock frequency for *SER_Clock*. The intermediate clock is generated from a (M+1) divider clocked at 100 MHz.
[15:12]	R/W	0x0	N_Divisor	Final clock frequency for *SER_Clock*. The final clock is generated from a 2^N divider clocked by the intermediate clock.
[11:10]	R	00	Reserved	Reserved and always reads zero.
[09]	R/W	0	TriggerClock	Trigger clock select: =0, trigger on Phase Clock =1, trigger on Servo Clock
[08]	R/W	0	TriggerEdge	Active clock edge select: =0, select rising edge =1, select falling edge
[07:04]	R/W	0x0	TriggerDelay	Trigger delay program relative to the active edge of the trigger clock. Units are in increments of 20 usec.
[03:00]	R	0x2	ProtocolCode	This read-only bit field is used to read the serial encoder interface protocol supported by the FPGA. A value of **$2** defines this as **SSI** protocol.

Channel Control Registers

X:$78Bn0, X:$78Bn4, X:$78Bn8, X:$78BnC where: n=2 for axes 1-4
n=3 for axes 5-8

Channel 1	X:$78B20	**Channel 5**	X:$78B30
Channel 2	X:$78B24	**Channel 6**	X:$78B34
Channel 3	X:$78B28	**Channel 7**	X:$78B38
Channel 4	X:$78B2C	**Channel 8**	X:$78B3C

Each channel has its own Serial Encoder Command Control Register defining functionality parameters. Parameters such as setting the number of position bits in the serial bit stream, enabling/disabling channels through the *SENC_MODE* **(**when this bit is cleared, the serial encoder pins of that channel are tri-stated), enabling/disabling communication with the encoder using the trigger control bit.

[23:16]	15	14	13	12	11	10	[9:6]	[5:0]
	Parity Type		Trigger Mode	Trigger Enable	GtoB	Rx data ready /Senc Mode		PositionBits/ Resolution

Bit	Type	Default	Name	Description
[23:16]	R	0x00	Reserved	Reserved and always reads zero.
[15:14]	R/W	0x00	Parity Type	Parity Type of the received data: 00=None 10=Even 01=Odd 11=Reserved
[13]	R/W	0	Trigger Mode	Trigger Mode to initiate communication: 0= continuous trigger 1= one-shot trigger All triggers occur at the defined Phase/Servo clock edge and delay setting.
[12]	R/W	0	Trigger Enable	0= disabled 1= enabled This bit must be set for either trigger mode. If the Trigger Mode bit is set for one-shot mode, the hardware will automatically clear this bit after the trigger occurs.
[11]	R/W	0	Convert G to B	Gray code to Binary conversion: 0=Binary 1=Gray
[10]	R	0	RxData Ready	This read-only bit provides the received data status. It is low while the interface logic is communicating (busy) with the serial encoder. It is high when all the data has been received and processed.
	W	0	SENC_MODE	This write-only bit is used to enable the output drivers for the SENC_SDO, SENC_CLK, SENC_ENA pins for each respective channel.
[09:06]	R	0x0	Reserved	Reserved and always reads zero.
[05:00]	W	0x00	Position Bits	This bit field is used to define the number of position data bits or encoder resolution: Range is 12 – 40 (001100 –101000)

SSI Data Registers

The SSI data is conveyed into 4 memory locations; Serial Encoder Data A, B, C, and D.

The Serial Encoder Data A register holds the 24 bits of the encoder position data. If the data exceeds the 24 available bits in this register, the upper overflow bits are LSB justified and readable in the Serial Encoder Data B, which also holds the parity error flag.
Serial Encoder Data C, and D registers are reserved and always read zero.

Serial Encoder Data B			**Serial Encoder Data A**
23	[22:08]	[07:0]	[23:0]
Parity Err		Position Data [31:24]	Position Data [23:0]

	SSI Encoder Data A	**SSI Encoder Data B**
Channel 1	Y:$78B20	Y:$78B21
Channel 2	Y:$78B24	Y:$78B25
Channel 3	Y:$78B28	Y:$78B29
Channel 4	Y:$78B2C	Y:$78B2D
Channel 5	Y:$78B30	Y:$78B31
Channel 6	Y:$78B34	Y:$78B35
Channel 7	Y:$78B38	Y:$78B39
Channel 8	Y:$78B3C	Y:$78B3D

Data Registers C and D are listed here for future use and documentation purposes only. They do not pertain to the SSI setup and always read zero.

	SSI Encoder Data C	**SSI Encoder Data D**
Channel 1	Y:$78B22	Y:$78B23
Channel 2	Y:$78B26	Y:$78B27
Channel 3	Y:$78B2A	Y:$78B28
Channel 4	Y:$78B2E	Y:$78B2F
Channel 5	Y:$78B32	Y:$78B33
Channel 6	Y:$78B36	Y:$78B37
Channel 7	Y:$78B3A	Y:$78B38
Channel 8	Y:$78B3E	Y:$78B3F

SSI Control Registers Setup Example

Channel 1 is driving a 25-bit (13-bit Singleturn, 12-bit Multiturn) SSI encoder. The encoder outputs binary data with no parity, and requires a 1 MHz serial clock.

Global Control Register

The Global Control register is a 24-bit hexadecimal word which is set up as follows:

$$Ser\_Clock = \frac{100}{(M+1) \times 2^N}\ MHz$$

=0 Rising Edge
=1 Falling Edge

=0 Trigger on Phase
=1 Trigger on Servo

Typically =0

$2 for SSI

Description:	M Divisor								N Divisor				0	0	clock	Edge	Trigger Delay				Protocol			
Bit #:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Hex ($):	**6**				**3**				**0**				**0**				**0**				**2**			

Field	Value	Notes	Global Control Word
M divisor	=99	Hex 0x63	$630002
N divisor	=0	Hex 0x0	
Trigger clock	=0	Trigger on Phase (recommended)	
Trigger Edge	=0	Rising edge (recommended)	
Trigger Delay	=0	No delay (typical)	
Protocol Code	=2	Hex 0x2, SSI protocol	

Channel Control Register

The Channel Control register is a 24-bit hexadecimal word which is set up as follows:

=0 Disabled
=1 Enabled

=00 None
=01 Odd
=10 Even

=0 Continuous
=1 One shot

=0 Disabled
=1 Enabled

Encoder Resolution (ST+MT)

Description:	Reserved (always 0)								Parity Type		Trigger Mode	Trigger Enable	0	Senc Mode	Reserved (always 0)				Bit Length					
Bit #:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1	0	0	1
Hex ($):	**0**				**0**				**1**				**4**				**1**				**9**			

Field	Value	Notes	Channel Control Word
Parity Type	=0	Hex 0x00	$001419
Trigger Mode	=0	Continuous trigger (typical)	
Trigger Enable	=1	Enable	
Gray / Binary	=0	Binary	
Data Ready / Senc Mode	=1	Enable serial driver	
Protocol Bits	=25	Hex 0x19	

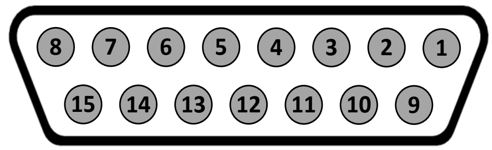
Control Registers Power-On PLC

The global and channel control words have to be executed once on power-up:

```
//=========================== NOTES ABOUT THIS PLC EXAMPLE ================================//
// This PLC example utilizes: - M5990 through M5991
//                            - Coordinate system 1 Timer 1
// Make sure that current and/or future configurations do not create conflicts with
// these parameters.
//=========================================================================================//

M5990..5991->* ; Self-referenced M-Variables
M5990..5991=0  ; Reset at download
//========================= GLOBAL CONTROL REGISTERS ======================================//
#define SSIGlobalCtrl1_4      M5990   ; Channels 1-4 SSI global control register
SSIGlobalCtrl1_4->X:$78B2F,0,24,U     ; Channels 1-4 SSI global control register address
//======================== CHANNEL CONTROL REGISTERS ======================================//
#define Ch1SSICtrl            M5991   ; Channel 1 SSI control register
Ch1SSICtrl->X:$78B20,0,24,U ; Channel 1 SSI control register Address

//========= POWER-ON PLC EXAMPLE, GLOBAL & CHANNEL CONTROL REGISTERS ======================//
Open PLC 1 Clear
SSIGlobalCtrl1_4=$630002      ; Trigger at Phase, 1 MHz serial Clock (M=99, N=0)-User Input
Ch1SSICtrl=$001419            ; Channel 1 SSI control register -User Input

I5111=500*8388608/I10 while(I5111>0) endw    ; ½ sec delay
Dis plc 1                     ; Execute once on power-up or reset
Close
//=========================================================================================//
```

X1-X8: Encoder Feedback, EnDat 2.1/2.2

X1-X8: D-sub DA-15F
Mating: D-Sub DA-15M



Pin #	Symbol	Function	Notes
1			Unused
2			Unused
3			Unused
4	EncPwr	Output	Encoder Power 5 Volts
5	Data-	Input	Data- packet
6	Clock-	Output	Serial Encoder Clock-
7			Unused
8			Unused
9			Unused
10			Unused
11			Unused
12	GND	Common	Common Ground
13	Clock+	Output	Serial Encoder Clock+
14	Data+	Input	Data+ Packet
15			Unused

Note

- Some EnDat devices require 24V power which has to be brought in externally. Pins 4, and 12 are unused in this case, leave floating.
- Hardware capture is not available with Serial encoders

Configuring EnDat

Configuring the EnDat protocol requires the programming of two essential control registers:

- Global Control Registers
- Channel Control Registers

The resulting data is found in:

- EnDat Data Registers

Global Control Registers

X:$78BnF (default value: $002003) where n=2 for axes 1-4
n=3 for axes 5-8

	Global Control Register
Axes 1-4	X:$78B2F
Axes 5-8	X:$78B3F

The Global Control register is used to program the serial encoder interface clock frequency. SENC_CLK is the serial data clock transmitted from the Brick to the encoder. It is used by the encoder to clock in data transmitted from the Brick, and clock out data from the encoder:

$$\text{Senc\_Clock} = \frac{100}{25 \times (M+1) \times 2^N}$$

M	N	Serial Clock Frequency
0	0	4.0 MHz
0	2	1.0 MHz
0	3	500 KHz
0	4	250 KHz
…	…	…

Default Settings M=0, N=2 => 1 MHz transfer rate

There are two external trigger sources; phase and servo. Bits [9:8] in the Global Control register are used to select the source and active edge to use as the internal serial encoder trigger. The internal trigger is used by all four channels to initiate communication with the encoder. To compensate for external system delays, this trigger has a programmable 4-bit delay setting in 20 µsec increments.

<table>
<tr><td>23--16</td><td>15--12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>M_Divisor</td><td>N_Divisor</td><td></td><td></td><td>Trigger Clock</td><td>Trigger Edge</td><td colspan="4">Trigger Delay</td><td colspan="4">Protocol Code</td></tr>
</table>

Bit	Type	Default	Name	Description
[23:16]	R/W	0x00	M_Divisor	Intermediate clock frequency for *SER_Clock*. The intermediate clock is generated from a (M+1) divider clocked at 100 MHz.
[15:12]	R/W	0x2	N_Divisor	Final clock frequency for *SER_Clock*. The final clock is generated from a 2^N divider clocked by the intermediate clock.
[11:10]	R	00	Reserved	Reserved and always reads zero.
[09]	R/W	0	TriggerClock	Trigger clock select: 0= PhaseClock 1= ServoClock
[08]	R/W	0	TriggerEdge	Active clock edge select: 0= rising edge 1= falling edge
[07:04]	R/W	0x0	TriggerDelay	Trigger delay program relative to the active edge of the trigger clock. Units are in increments of 20 usec.
[03:00]	R	0x3	ProtocolCode	This read-only bit field is used to read the serial encoder interface protocol supported by the FPGA. A value of **0x3** defines this protocol as **EnDat**.

Channel Control Registers

X:$78Bn0, X:$78Bn4, X:$78Bn8, X:$78BnC where: n=2 for axes 1-4
n=3 for axes 5-8

Channel 1	X:$78B20	**Channel 5**	X:$78B30
Channel 2	X:$78B24	**Channel 6**	X:$78B34
Channel 3	X:$78B28	**Channel 7**	X:$78B38
Channel 4	X:$78B2C	**Channel 8**	X:$78B3C

Each channel has its own Serial Encoder Command Control Register defining functionality parameters. Parameters such as setting the number of position bits in the serial bit stream, enabling/disabling channels through the *SENC_MODE* **(**when this bit is cleared, the serial encoder pins of that channel are tri-stated), enabling/disabling communication with the encoder using the trigger control bit.

23	22	[21:16]	15	14	13	12	11	10	[9:6]	[5:0]
		Command Code			Trigger Mode	Trigger Enable		Rxdata ready /Senc Mode		PositionBits/ Resolution

Bit	**Type**	**Default**	**Name**	**Description**
[23:22]	R	0x000	Reserved	Reserved and always reads zero.
[21:16]	R	0x00	Command Code	($38) 111000 – Encoder to Send Position (EnDat2.2 only) ($15) 010101 – Encoder to Receive Reset (EnDat2.2 only) ($07) 000111 – Encoder to Send Position (EnDat 2.1 & 2.2) ($2A)101010 – Encoder to Receive Reset (EnDat 2.1 & 2.2)
[15:14]	R	00	Reserved	Reserved and always reads zero.
[13]	R/W	0	Trigger Mode	Trigger Mode: 0= continuous trigger 1= one-shot trigger All triggers occur at the defined Phase/Servo clock edge and delay setting. See **Global Control** register for these settings.
[12]	R/W	0	Trigger Enable	Enable trigger: 0= disabled 1= enabled This bit must be set for either trigger mode. If the Trigger Mode bit is set for one-shot mode, the hardware will automatically clear this bit after the trigger occurs.
[11]	R/W	0	Reserved	Reserved and always reads zero.
[10]	R	0	RxData Ready	This read-only bit provides the received data status. It is low while the interface logic is communicating (busy) with the serial encoder. It is high when all the data has been received and processed.
	W	0	SENC_MODE	This write-only bit is used to enable the output drivers for the SENC_SDO, SENC_CLK, SENC_ENA pins for each respective channel.
[09:06]	R	0x0	Reserved	Reserved and always reads zero.
[05:00]	W	0x00	Position Bits	This bit field is used to define the number of position data bits or encoder resolution: Range is 12 – 40 (001100 –101000)

EnDat Data Registers

The EnDat data is conveyed into 4 memory locations; EnDat Data A, B, C, and D.

The EnDat Data A register holds the 24 bits of the encoder position data. If the data exceeds the 24 available bits in this register, the upper overflow bits are LSB justified and readable in the EnDat Data B register, which also holds error flags. The error bit flag is always returned by the encoder, except for a Reset command. The *CRC* error bit is set if the return data fails the *CRC* verification. The timeout error flag is set if the SEIGATE3 does not receive a response from the encoder.
EnDat Data C, and D registers are reserved and always read zero.

EnDat Data B					**EnDat Data A**
23	22	21	[20:16]	[15:0]	[23:0]
TimeOut Err	CRC Err	Err flag		Position Data [39:24]	Position Data [23:0]

	EnDat Data A	**EnDat Data B**
Channel 1	Y:$78B20	Y:$78B21
Channel 2	Y:$78B24	Y:$78B25
Channel 3	Y:$78B28	Y:$78B29
Channel 4	Y:$78B2C	Y:$78B2D
Channel 5	Y:$78B30	Y:$78B31
Channel 6	Y:$78B34	Y:$78B35
Channel 7	Y:$78B38	Y:$78B39
Channel 8	Y:$78B3C	Y:$78B3D

EnDat Registers C and D are listed here for future use and documentation purposes only. They do not pertain to the EnDat setup and always read zero.

	EnDat Data C	**EnDat Data D**
Channel 1	Y:$78B22	Y:$78B23
Channel 2	Y:$78B26	Y:$78B27
Channel 3	Y:$78B2A	Y:$78B28
Channel 4	Y:$78B2E	Y:$78B2F
Channel 5	Y:$78B32	Y:$78B33
Channel 6	Y:$78B36	Y:$78B37
Channel 7	Y:$78B3A	Y:$78B38
Channel 8	Y:$78B3E	Y:$78B3F

EnDat Control Registers Setup Example

Channel 1 is driving a 37-bit (25-bit Singleturn, 12-bit Multiturn) EnDat 2.2 encoder. The encoder requires a 4 MHz serial clock.

Global Control Register

The Global Control register is a 24-bit hexadecimal word which is set up as follows:

$$Senc\_Clock = \frac{100}{25 \times (M+1) \times 2^N}$$

=0 Rising Edge
=1 Falling Edge

=0 Trigger on Phase
=1 Trigger on Servo

Typically =0

$3 for EnDat

Description:	M Divisor								N Divisor				0	0	clock	Edge	Trigger Delay				Protocol			
Bit #:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Hex ($):	0				0				0				0				0				3			

Field	Value	Notes	Global Control Word
M divisor	=0	Hex 0x00	$000003
N divisor	=0	Hex 0x0	
Trigger clock	=0	Trigger on Phase (recommended)	
Trigger Edge	=0	Rising edge (recommended)	
Trigger Delay	=0	No delay (typical)	
Protocol Code	=3	Hex 0x3, EnDat	

Channel Control Register

The Channel Control register is a 24-bit hexadecimal word which is set up as follows:

=111000 ($38) Send Position (EnDat 2.2 only)
=010101 ($15) Reset (EnDat 2.2 only)

=000111 ($07) Send Position (EnDat 2.1 / 2.2)
=101010 ($2A) Reset (EnDat 2.1 / 2.2)

=0 Disabled
=1 Enabled

=0 Continuous
=1 One shot

=0 Disabled
=1 Enabled

Encoder Resolution (ST+MT)

Description:	0	0	Command Code						0	0	Trigger Mode	Trigger Enable	0	Senc Mode	Reserved (always 0)				Bit Length (Resolution)					
Bit #:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	0	1	1	1	0	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	1	0	1
Hex ($):	3				8				1				4				2				5			

Field	Value	Notes	Channel Control Word
Command code	=$38	Hex 0x38 for EnDat 2.2 only	$381425
Trigger Mode	=0	Continuous trigger (typical)	
Trigger Enable	=1	Enable	
Data Ready / Senc Mode	=1	Enable serial driver	
Protocol Bits	=37	Hex 0x25	

Control Registers Power-On PLC

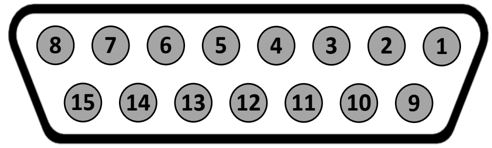
The Global and Channel Control words have to be executed once on power-up

```
//=========================== NOTES ABOUT THIS PLC EXAMPLE ================================//
// This PLC example utilizes: - M5990 through M5991
//                            - Coordinate system 1 Timer 1
// Make sure that current and/or future configurations do not create conflicts with
// these parameters.
//=========================================================================================//

M5990..5991->* ; Self-referenced M-Variables
M5990..5991=0  ; Reset at download
//========================= GLOBAL CONTROL REGISTERS ======================================//
#define EnDatGlobalCtrl1_4    M5990   ; Channels 1-4 EnDat global control register
EnDatGlobalCtrl1_4->X:$78B2F,0,24,U   ; Channels 1-4 EnDat global control register address
//======================== CHANNEL CONTROL REGISTERS ======================================//
#define Ch1EnDatCtrl          M5991   ; Channel 1 EnDat control register
Ch1EnDatCtrl->X:$78B20,0,24,U ; Channel 1 EnDat control register Address

//========= POWER-ON PLC EXAMPLE, GLOBAL & CHANNEL CONTROL REGISTERS ======================//
Open PLC 1 Clear
EnDatGlobalCtrl1_4=$3  ; Trigger at Phase, 4MHz serial Clock -User Input
Ch1EnDatCtrl=$381425   ; Channel 1 EnDat control register -User Input

I5111=500*8388608/I10 while(I5111>0) endw    ; ½ sec delay
Dis plc 1                     ; Execute once on power-up or reset
Close
//=========================================================================================//
```

Note

Some EnDat2.2 Encoders do not support additional information with the $38 (111000) command code. Try using $07 (000111) command code if you cannot see data in the Serial Data Register A, or in the position window (after setting up the Encoder Conversion Table).

X1-X8: Encoder Feedback, BiSS C/B

X1-X8: D-sub DA-15F **Mating: D-Sub DA-15M**			
Pin #	**Symbol**	**Function**	**Notes**
1			Unused
2			Unused
3			Unused
4	EncPwr	Output	Encoder Power 5 Volts
5	Data-	Input/Output	Data- packet, SLO-
6	Clock-	Output	Serial Encoder Clock-, MO-
7			Unused
8			Unused
9			Unused
10			Unused
11			Unused
12	GND	Common	Common Ground
13	Clock+	Output	Serial Encoder Clock+ , MO+
14	Data+	Input/Output	Data+ Packet, SLO+
15			Unused

Note

- Some BiSS devices require 24V power which has to be brought in externally. Pins 4, and 12 are unused in this case, leave floating.
- Hardware capture is not available with Serial encoders

Configuring BiSS

Configuring the BiSS protocol requires the programming of two essential control registers:

- Global Control Registers
- Channel Control Registers

The resulting data is found in:

- BiSS-C/BiSS-B Data Registers

Global Control Registers

X:$78BnF (default value: $18000B) where n=2 for axes 1-4
n=3 for axes 5-8

	Global Control Register
Axes 1-4	X:$78B2F
Axes 5-8	X:$78B3F

The Global Control register is used to program the serial encoder interface clock frequency *SER_Clock* and configure the serial encoder interface trigger clock. *SER_Clock* is generated from a two-stage divider clocked at 100 MHz as follows:

$$\text{Ser\_Clock}=\frac{100}{(M+1)\times 2^{N}} \quad \text{MHz}$$

M	N	Clock Frequency
49	0	2.0 MHz
99	0	1.0 MHz
99	1	500.0 KHz
99	2	250.0 KHz
…	…	

Default Settings: M=24, N=0 => 4 MHz transfer rates

There are two external trigger sources; phase and servo. Bits [9:8] in the Global Control register are used to select the source and active edge to use as the internal serial encoder trigger. The internal trigger is used by all four channels to initiate communication with the encoder. To compensate for external system delays, this trigger has a programmable 4-bit delay setting in 20 µsec increments.

23--16	15--12	11	10	9	8	7	6	5	4	3	2	1	0
M_Divisor	N_Divisor			Trigger Clock	Trigger Edge	Trigger Delay				Protocol Code			

Bit	Type	Default	Name	Description
[23:16]	R/W	0x18	M_Divisor	Intermediate clock frequency for *SER_Clock*. The intermediate clock is generated from a (M+1) divider clocked at 100 MHz.
[15:12]	R/W	0x0	N_Divisor	Final clock frequency for *SER_Clock*. The final clock is generated from a 2^N divider clocked by the intermediate clock.
[11:10]	R	00	Reserved	Reserved and always reads zero.
[09]	R/W	0	TriggerClock	Trigger clock select: 0= PhaseClock 1= ServoClock
[08]	R/W	0	TriggerEdge	Active clock edge select: 0= rising edge 1= falling edge
[07:04]	R/W	0x0	TriggerDelay	Trigger delay program relative to the active edge of the trigger clock. Units are in increments of 20 usec.
[03:00]	R	0xB	ProtocolCode	This read-only bit field is used to read the serial encoder interface protocol supported by the FPGA. A value of **$B** defines this protocol as **BiSS**.

Channel Control Registers

X:$78Bn0, X:$78Bn4, X:$78Bn8, X:$78BnC where: n=2 for axes 1-4
n=3 for axes 5-8

Channel 1	X:$78B20	**Channel 5**	X:$78B30
Channel 2	X:$78B24	**Channel 6**	X:$78B34
Channel 3	X:$78B28	**Channel 7**	X:$78B38
Channel 4	X:$78B2C	**Channel 8**	X:$78B3C

Each channel has its own Serial Encoder Command Control Register defining functionality parameters. Parameters such as setting the number of position bits in the serial bit stream, enabling/disabling channels through the *SENC_MODE* **(**when this bit is cleared, the serial encoder pins of that channel are tri-stated), enabling/disabling communication with the encoder using the trigger control bit.

[23:16]	15	14	13	12	11	10	9	[8:6]	[5:0]
CRC Mask	=0 BiSS-C =1 BiSS-B	MCD	Trigger Mode	Trigger Enable		Rxdataready SencMode		Status Bits	PositionBits/ Resolution

Bit	Type	Default	Name	Description
[23:16]	R/W	0x21	CRC_Mask	This bit field is used to define the CRC polynomial used for the position and status data. The 8-bit mask is to define any 4-bit to 8-bit CRC polynomial. The mask bits M[7:0] represent the coefficients [8:1], respectively, in the polynomial: $M_7x_8 + M_6x_7 + M_5x_6 + M_4x_5 + M_3x_4 + M_2x_3 + M_1x_2 + M_0x_1 + 1$. The coefficient for x_0 is always 1 and therefore not included in the mask. An all zero mask indicates no CRC bits in the encoder data. Most common setting: ($21) 00100001 = $x_6 + x_1 + 1$ (typical for Renishaw) ($09) 00001001 = $x_4 + x_1 + 1$
[15]	R/W	0	BiSS B/C	This bit is used to select the BiSS protocol mode (=0 BiSS-C, =1 BiSS-B)
[14]	R/W	0	MCD	This bit is used to enable support for the optional MCD bit in BiSS-B mode. Setting this bit has no effect if the BiSS-B mode is not selected.
[13]	R/W	0	Trigger Mode	Trigger Mode to initiate communication: 0= continuous trigger 1= one-shot trigger All triggers occur at the defined Phase/Servo clock edge and delay setting.
[12]	R/W	0	Trigger Enable	0= disabled 1= enabled This bit must be set for either trigger mode. If the Trigger Mode bit is set for one-shot mode, the hardware will automatically clear this bit after the trigger occurs.
[11]		0	Reserved	Reserved and always reads zero.
[10]	R	0	RxData Ready	This read-only bit provides the received data status. It is low while the interface logic is communicating (busy) with the serial encoder. It is high when all the data has been received and processed.

	W	0	SENC_MODE	This write-only bit is used to enable the output drivers for the SENC_SDO, SENC_CLK, SENC_ENA pins for each respective channel.
[09]		0x0	Reserved	Reserved and always reads zero.
[08:06]	R/W	000	Status Bits	This bit field is used to define the number of status bits in the encoder data. The valid range of settings is 0 – 6 (000 – 110). The status bits are assumed to always follow after the position data and before the CRC.
[05:00]	W	0x00	Position Bits	This bit field is used to define the number of position data bits or encoder resolution: Range is 12 – 40 (001100 –101000) The position bits are assumed to be in binary MSB-first format: $12 for 18-bit | $1A for 26-bit | $20 for 32-bit

BiSS Data Registers

The BiSS data is conveyed into 4 memory locations; Serial Encoder Data A, B, C, and D.

The Serial Encoder Data A register holds the 24 bits of the encoder position data. If the data exceeds the 24 available bits in this register, the upper overflow bits are LSB justified and readable in the Serial Encoder Data B, which also holds status and error bits. Serial Encoder Data C, and D registers are reserved and always read zero.

BiSS Data B				**BiSS Data A**
23	22	[21:16]	[15:0]	[23:0]
TimeOut Err	CRC Err	Status Data	Position Data [39:24]	Position Data [23:0]

	BiSS Encoder Data A	**BiSS Encoder Data B**
Channel 1	Y:$78B20	Y:$78B21
Channel 2	Y:$78B24	Y:$78B25
Channel 3	Y:$78B28	Y:$78B29
Channel 4	Y:$78B2C	Y:$78B2D
Channel 5	Y:$78B30	Y:$78B31
Channel 6	Y:$78B34	Y:$78B35
Channel 7	Y:$78B38	Y:$78B39
Channel 8	Y:$78B3C	Y:$78B3D

Data Registers C and D are listed here for future use and documentation purposes only. They do not pertain to the BiSS setup and always read zero.

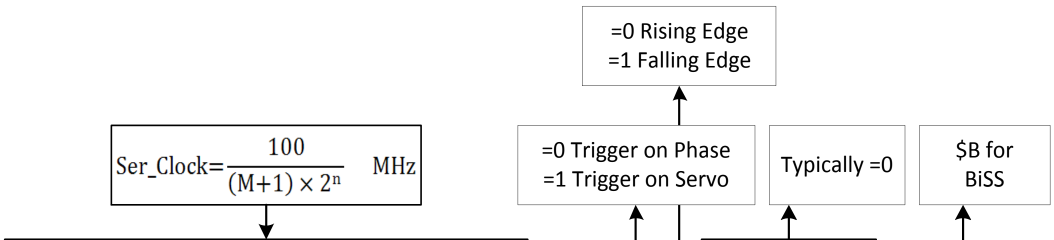
	BiSS Encoder Data C	**BiSS Encoder Data D**
Channel 1	Y:$78B22	Y:$78B23
Channel 2	Y:$78B26	Y:$78B27
Channel 3	Y:$78B2A	Y:$78B28
Channel 4	Y:$78B2E	Y:$78B2F
Channel 5	Y:$78B32	Y:$78B33
Channel 6	Y:$78B36	Y:$78B37
Channel 7	Y:$78B3A	Y:$78B38
Channel 8	Y:$78B3E	Y:$78B3F

BiSS Control Registers Setup Example

Channel 1 is driving an 18-bit Renishaw resolute BiSS-C encoder. The encoder requires a 1 MHz serial clock, and has 2 status bits.

Global Control Register

The Global Control register is a 24-bit hexadecimal word which is set up as follows:

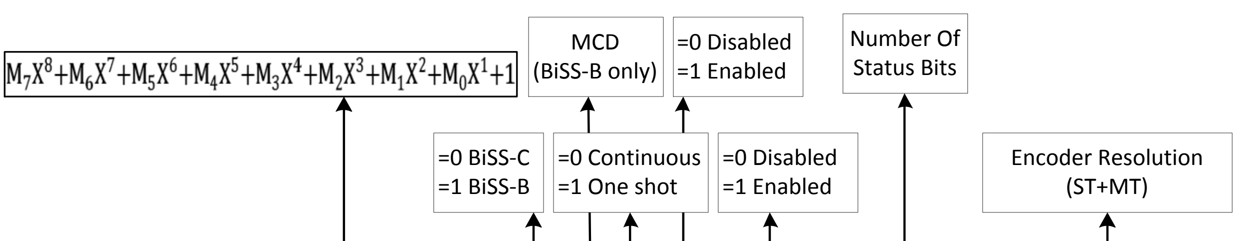


Description:	M Divisor								N Divisor				0	0	clock	Edge	Trigger Delay				Protocol			
Bit #:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1
Hex:	6				3				0				0				0				B			

Field	Value	Notes	Global Control Word
M divisor	=99	Hex 0x63	$63000B
N divisor	=0	Hex 0x0	
Trigger clock	=0	Trigger on Phase (recommended)	
Trigger Edge	=0	Rising edge (recommended)	
Trigger Delay	=0	No delay (typical)	
Protocol Code	=11	Hex 0xB, BiSS protocol	

Channel Control Register

The Channel Control register is a 24-bit hexadecimal word set up as follows:



Description:	CRC Mask								BiSS Type	MCD	Trigger Mode	Trigger Enable	0	Senc Mode	0	Status		Bit Length (Resolution)						
Bit #:	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Binary:	0	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0	1	0	0	1	0
Hex ($):	2				1				1				4				9				2			

Field	Value	Notes	Channel Control Word
CRC Mask	=33	Hex 0x21 typical for Renishaw	$211492
BiSS Type	=0	for BiSS-C	
Trigger Mode	=0	Continuous trigger (typical)	
Trigger Enable	=1	Enable	
Data Ready / Senc Mode	=1	Enable serial driver	
Status Bits	=2	Binary 010	
Protocol Bits	=18	Binary 010010	

Control Registers Power-On PLC

The Global and Channel Control words have to be executed once on power-up

```
//=========================== NOTES ABOUT THIS PLC EXAMPLE ================================//
// This PLC example utilizes: - M5990 through M5991
//                            - Coordinate system 1 Timer 1
// Make sure that current and/or future configurations do not create conflicts with
// these parameters.
//=========================================================================================//
M5990..5991->* ; Self-referenced M-Variables
M5990..5991=0  ; Reset at download
//========================= GLOBAL CONTROL REGISTERS ======================================//
#define SSIGlobalCtrl1_4      M5990   ; Channels 1-4 BiSS global control register
SSIGlobalCtrl1_4->X:$78B2F,0,24,U     ; Channels 1-4 BiSS global control register address
//======================== CHANNEL CONTROL REGISTERS ======================================//
#define Ch1SSICtrl            M5991   ; Channel 1 BiSS control register
Ch1SSICtrl->X:$78B20,0,24,U           ; Channel 1 BiSS control register Address
//========= POWER-ON PLC EXAMPLE, GLOBAL & CHANNEL CONTROL REGISTERS ======================//
Open PLC 1 Clear
SSIGlobalCtrl1_4=$63000B      ; Trigger at Phase, 1 MHz serial Clock (M=99, N=0) -User Input
Ch1SSICtrl=$211492            ; Channel 1, BiSS-C protocol, 18-bit resolution    -User Input

I5111=500*8388608/I10 while(I5111>0) endw    ; ½ sec delay
Dis plc 1                     ; Execute once on power-up or reset
Close
//=========================================================================================//
```

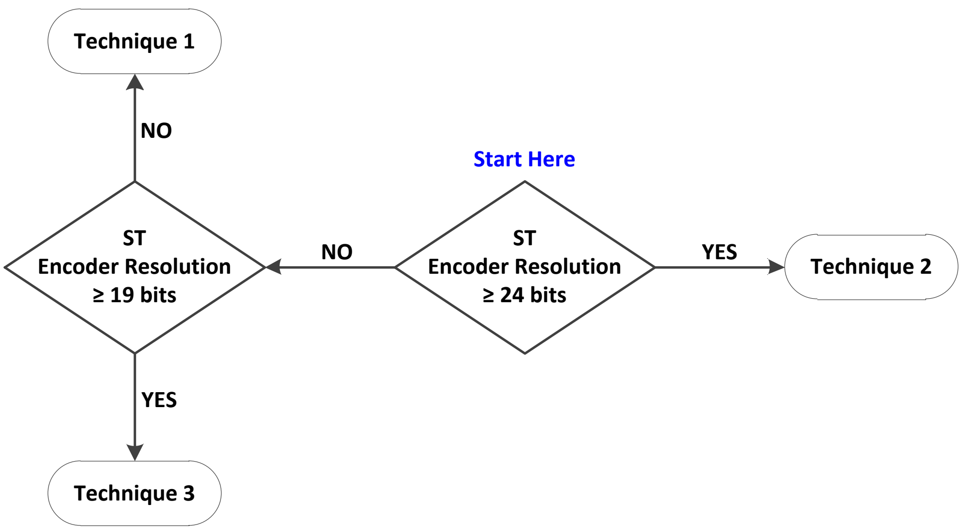
Setting Up SSI | EnDat | BiSS

In Turbo PMAC (i.e. Brick family), the absolute serial encoder data is brought in as an unfiltered parallel Y-word into the Encoder Conversion Table (ECT) where it is processed for the PMAC to use for on-going position in the motor servo-loop, power-on absolute position, and (power-on/on-going) phase referencing. In general, encoder data is left-shifted 5 bits in the ECT to provide fractional data. This process can cause saturation of certain registers with higher resolution absolute serial encoders, thus for this type of encoders, it is recommended to process the data as unshifted. Moreover, special considerations need to be taken in setting up commutation (for commutated motors, e.g. brushless).

Note

Details about registers' overflow and examples can be found in the appendix section.

The following flowchart summarizes the recommended method to use, regardless of the Multiturn (MT) data specification. It is only dependent on the Singleturn (ST) resolution (for rotary encoders) or protocol resolution (for linear scales).



Technique 1

This technique places the Least Significant Bit (LSB) of the serial data in bit 5 of the result register providing the 5 bits of "non-existent" fraction.

Technique 2

This technique places the LSB of the serial data in bit 0 of the result register, creating no fractional bits. It requires a dedicated Encoder Conversion Table (ECT) entry for commutation.

Technique 3

This technique processes the data for position similarly to Technique 1, but it requires a dedicated ECT entry for commutation.

Note

Some applications may require deviating from the suggested setup methods (e.g. extremely high resolution and speed requirements). Contact Delta Tau for assistance with these special cases.

Setup Summary

Encoder Conversion Table Processing:

Process	Technique 1	Technique 2	Technique 3
ECT for Position	From serial register A, 5-bit shift	From serial register A, no shift	From serial register A, 5-bit shift
ECT for Commutation	N/A	From serial register A, 18 bits, no shift, Offset=ST-18	From serial register A, 18 bits, no shift, Offset=ST-18

Note

ST is the Singleturn resolution (in bits) for rotary encoders. Similarly, this would be the protocol resolution (in bits) for linear scales.

The position and velocity pointers are then assigned to the "ECT for position" result:

Parameter	Technique 1/2/3
Position (Ixx03)	@ ECT position result
Velocity (Ixx04)	@ ECT position result (typically, with single source feedback)

Commutation Source And Type (for commutated motors, e.g. brushless)

With technique 1, if the Singleturn + Multiturn data bits fulfill 24 bits and are contiguous, then serial data register A can be used as the commutation source. Otherwise, the resulting register from the ECT for position is used for commutation (requires special settings for the commutation cycle size).
With techniques 2 and 3, the feedback source for commutation should come from its dedicated ECT.

Parameter	Technique 1		Technique 2/3
Commutation Source (Ixx83)	@ serial data register A	if ST+MT ≥ 24 bits	@ commutation ECT result
	@ ECT position result	if ST+MT < 24 bits	
Commutation Type (Ixx01)	= 3 (from Y register)	if ST+MT ≥ 24 bits	=1 (from X register)
	= 1 (from X register)	if ST+MT < 24 bits	

Note

Special considerations should be made if the Singleturn (ST) and Multiturn (MT) data bits are NOT contiguous (in consecutive fields). Contact Delta Tau for assistance with these special cases.

Note

Multiturn MT is equal to zero for encoders which do not possess Multiturn data bits.

Resolution Scale Factor (SF)

Parameter	Encoder Type	Technique 1/3	Technique 2
Resolution Scale Factor SF	Rotary [counts/rev]	$= 2^{ST}$	$= 2^{ST-5} = 2^{ST}/32$
	Linear [counts/user units]	= 1/RES	= 1/(32*RES)

Where ST: is the rotary encoder Singleturn resolution in bits
RES: is the linear scale resolution, in user units (e.g. mm)

Commutation Cycle Size

Parameter	Motor/Encoder	Technique 1		Technique 2/3
Ixx70	Rotary	= Number of pole pairs		
	Linear	= 1		
Ixx71	Rotary	$= SF = 2^{ST}$	if Ixx01=3	$= 2^{18}$ = 262144
		$= 32 * SF = 32 * 2^{ST}$	if Ixx01=1	
	Linear	= ECL * SF= ECL/RES	if Ixx01=3	$= ECL * SF / 2^{Offset}$ $= ECL/(RES*2^{Offset})$
		= 32 * ECL * SF = 32 * (ECL/RES)	if Ixx01=1	

Where ST: is the rotary encoder Singleturn resolution in bits
RES: is the linear scale resolution, in user units (e.g. mm)
ECL: is the electrical cycle length of the linear motor, same units as RES (e.g. mm)
Offset: is the ECT commutation Offset, it is (=ST-18 for rotary, or =RES-18 for linear)
SF: is the encoder resolution scale factor (calculated previously)

Position And Velocity Scale Factors, Position Error Limit

With technique 2, and technique 3 (with encoder resolutions greater than 20 bits), it is recommended to set the position and velocity scale factors to equal 1 and widen the position error limit. Otherwise, default values should be ok for all other cases. This alleviates register saturation(s), allows for higher commanded speed settings and easier PID (position-loop) tuning.

Parameter(s)	Technique 1	Technique 2	Technique 3	
Ixx08, Ixx09	= 96	= 1	= 96 = 1	for ST < 20 for ST $\geq$ 20
Ixx67	Default	= 8388607	= Default = 8388607	for ST < 20 for ST $\geq$ 20

Absolute Power-On Position And Phasing

Process	Technique 1	Technique 2	Technique 3
Absolute Position Read	From serial register A, automatic settings	From serial register A, scaling required	From serial register A, automatic settings
Absolute Phasing	Automatic settings, depending on ST+MT	From ECT for Comm., automatic settings	From ECT for Comm., automatic settings

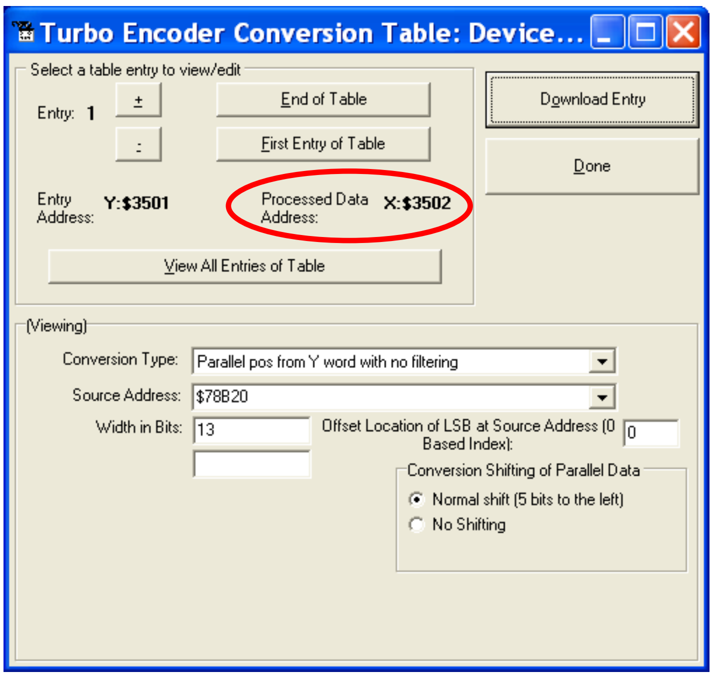
Technique 1 Example

Channel 1 is driving a 25-bit (13-bit Singleturn, 12-bit Multiturn) rotary serial encoder, or a linear scale with similar protocol resolution (13 bits, 1 micron).

Encoder Conversion Table - for position (Technique 1)

- Conversion Type: Parallel pos from Y word with no filtering
- Width in Bits: Singleturn/absolute resolution in bits (e.g. 13 bits)
- Offset Location of LSB: leave at zero
- Normal Shift (5 bits to the left)
- Source Address: serial data register A (see table below)
- Remember to click on Download Entry for the changes to take effect.

	Source Address (Serial Data Register A)			
Channel 1	Y:$78B20	Channel 5	Y:$78B30
Channel 2	Y:$78B24	Channel 6	Y:$78B34
Channel 3	Y:$78B28	Channel 7	Y:$78B38
Channel 4	Y:$78B2C	Channel 8	Y:$78B3C



This is a 2-line ECT entry, its equivalent script code:

```
I8000=$278B20          ; Unfiltered parallel pos of location Y:$78B20
I8001=$00D000          ; Width and Offset. Processed result at $3502
```

Typically, the position and velocity pointers are set to the processed data address (e.g. $3502):

```
I100=1                 ; Mtr#1 Active. Remember to activate the channel to see feedback
I103=$3502             ; Mtr#1 position loop feedback address
I104=$3502             ; Mtr#1 velocity loop feedback address
```

Note

At this point, you should be able to move the motor/encoder shaft by hand and see ‘motor’ counts in the position window.

Counts Per User Units (Technique 1)

With technique 1, the user should expect to see 2^{ST} counts per revolution for rotary encoders, and 1/Resolution counts per user unit for linear scales in the motor position window.

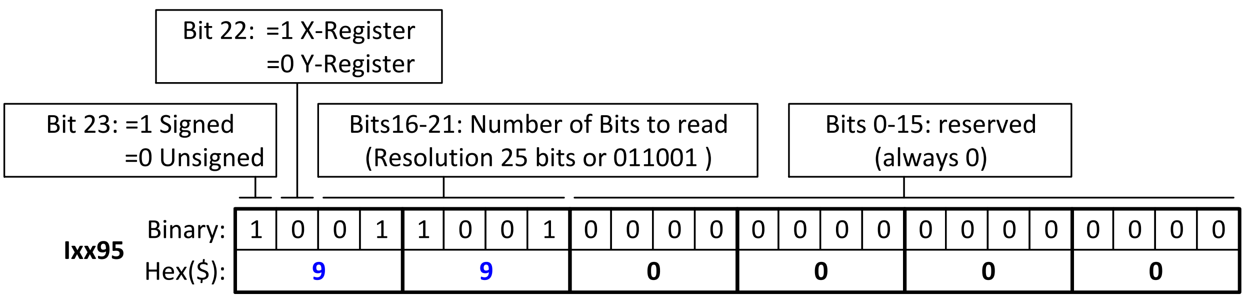
Examples: 25-bit rotary encoder (13-bit Singleturn): 2^{13}= 8,192 cts/rev
1-micron linear scale: 1/0.001= 1,000 cts/mm

Absolute Power-On Position Read (Technique 1)

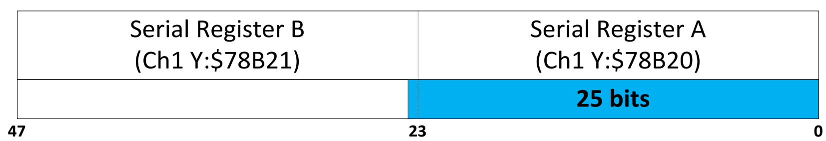
With Technique 1, the absolute power-on read can be performed using PMAC's automatic settings (Ixx80, Ixx10 and Ixx95).

Example 1: Channel 1 driving a 25-bit (13-bit single turn, 12-bit multi-turn) rotary serial encoder:

```
I180=2                          ; Absolute power-on read enabled
I110=$78B20                     ; Absolute power-on position address (ch1 serial data register A)
I195=$990000                    ; Parallel Read, 25 bits, Signed, from Y-Register –User Input
```



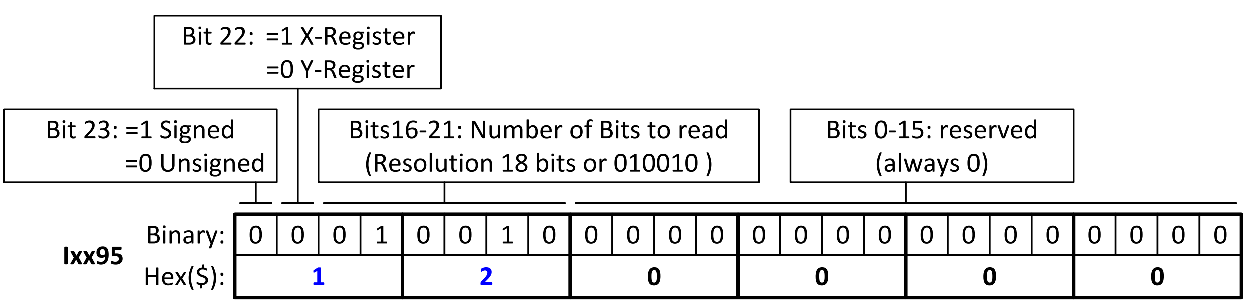
In this mode, PMAC reads and reports 25 bits from the consecutive serial data registers:



With the setting of Ixx80=2, the actual position is reported automatically on Power-up. Otherwise, a #1$* command is necessary to read and report the absolute position.

Example 2: Channel 1 driving an 18-bit (18-bit Singleturn, No Multiturn) absolute rotary serial encoder, or a similar protocol resolution (18 bits) linear scale:

```
I180=2                          ; Absolute power-on read enabled
I110=$78B20                     ; Absolute power-on position address (ch1 serial data register A)
I195=$120000                    ; Parallel Read, 18 bits, Unsigned, from Y-Register –User Input
```



In this mode, PMAC reads and reports 18 bits from the first serial data register:

Serial Data Register B (Ch1 Y:$78B21)	Serial Data Register A (Ch1 Y:$78B20)
	18 bits
47	23 … 0

With this setting of Ixx80=2, the actual position is reported automatically on Power-up. Otherwise, a #1$* command is necessary to read and report the absolute position.

Note

With absolute serial encoders (no multi-turn data), the power-on position format is set up for unsigned operation.

Note

The upper two fields in Ixx95 are the only relevant ones. Bits 0 through 15 are reserved and should always be set to 0.

Note

Some serial encoders use an external (not from the Brick) source for power. Make sure that this power is applied prior to performing an absolute read on power-up.

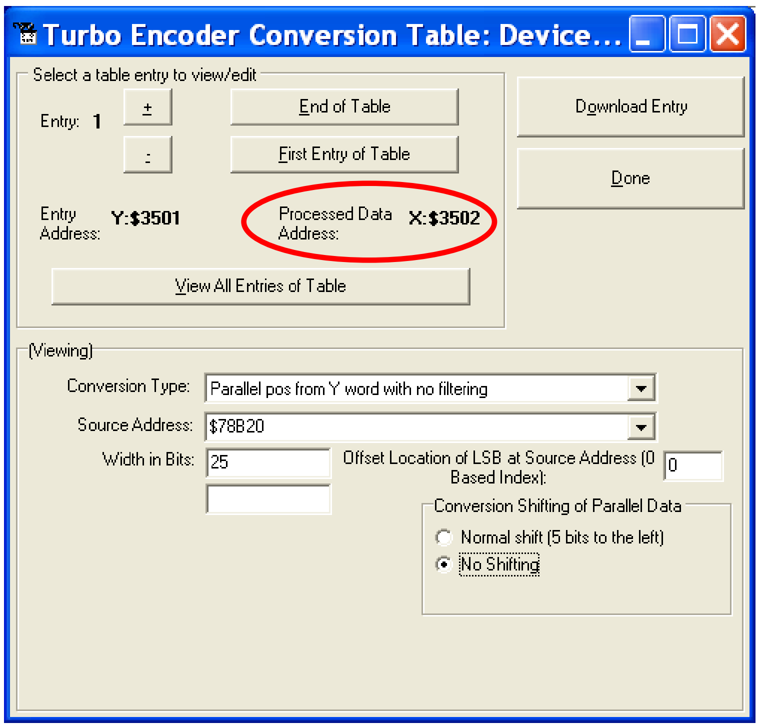
Technique 2 Example

Channel 1 is driving a 37-bit (25-bit Singleturn, 12-bit Multiturn) rotary serial encoder, or a linear scale with similar protocol resolution (25 bits, 10 nanometer).

Encoder Conversion Table – for position (Technique 2)

- Conversion Type: Parallel pos from Y word with no filtering
- Width in Bits: Singleturn/absolute resolution in bits (e.g. 25 bits)
- Offset Location of LSB: leave at zero
- No shifting
- Source Address: serial data register A (see table below)
- Remember to click on Download Entry for the changes to take effect.

	Source Address (serial data register A)		
Channel 1	Y:$78B20	**Channel 5**	Y:$78B30
Channel 2	Y:$78B24	**Channel 6**	Y:$78B34
Channel 3	Y:$78B28	**Channel 7**	Y:$78B38
Channel 4	Y:$78B2C	**Channel 8**	Y:$78B3C



This is a 2-line ECT entry, its equivalent script code:

```
I8000=$2F8B20           ; Unfiltered parallel pos of location Y:$78B20
I8001=$19000            ; Width and Offset. Processed result at $3502
```

Typically, the position and velocity pointers are set to the processed data address (e.g. $3502). Also, with technique 2, it is recommended to set the position and velocity scale factors to 1 and the position error limit to its maximum value:

```
I100=1                  ; Mtr#1 Active. Remember to activate the channel to see feedback
I103=$3502              ; Mtr#1 position loop feedback address
I104=$3502              ; Mtr#1 velocity loop feedback address
I108=1                  ; Mtr#1 position-loop scale factor
I109=1                  ; Mtr#1 velocity-loop scale factor
I167=8388607            ; Mtr#1 Position Error Limit
```

Note

At this point, you should be able to move the motor/encoder shaft by hand and see 'motor' counts in the position window

Counts Per User Units (Technique 2)

With technique 2, the user should expect to see $2^{ST-5} = 2^{ST}/32$ counts per revolution for rotary encoders, and 1/(32*Resolution) counts per user unit for linear scales in the motor position window.

Examples: 37-bit rotary encoder (25-bit Singleturn): $2^{25}/32$= 1,048,576 cts/rev
10-nanometer linear scale: 1/(32*0.000010)= 3,125 cts/mm

Encoder Conversion Table - for commutation (Technique 2)

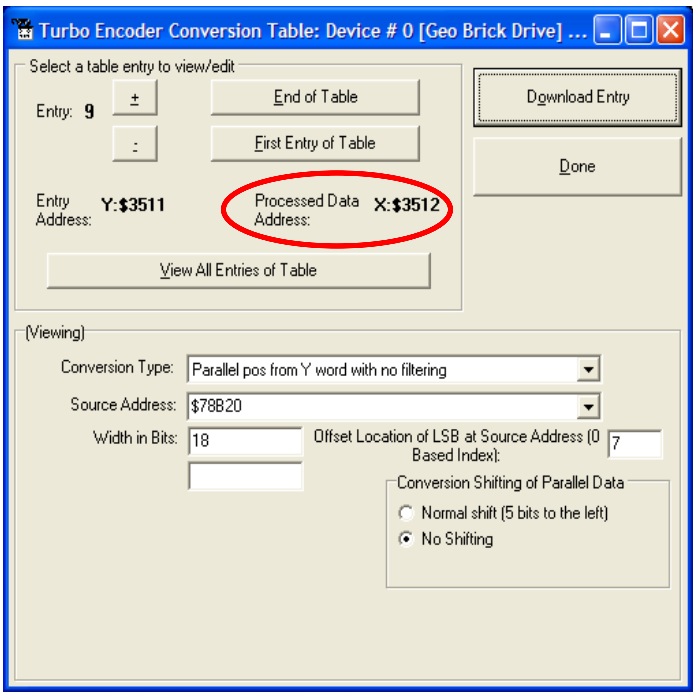
Commutation with Turbo PMAC does not require high resolution data. With Technique 2, it is recommended to fix it at 18 bits. This will also eliminate quantization noise.

Note

It is recommended to insert the commutation ECT entries after all of the position ECT entries have been configured.

Assuming that eight encoders have been configured for position, the first ECT for commutation for the first motor would be at entry number nine:

- Conversion Type: Parallel pos from Y word with no filtering
- Width in Bits: 18
- Offset Location of LSB: = Singleturn/protocol bits – 18 (e.g. 25-18=7)
- No shifting
- Source Address: serial data register A (same as position ECT for this motor)
- Remember to click on Download Entry for the changes to take effect.



This is a 2-line ECT entry, its equivalent script code:

```
I8016=$2F8B20          ; Unfiltered parallel pos of location Y:$78B20 –User Input
I8017=$12007           ; Width and Offset. Processed result at X:$3512 –User Input
```

Note

Record the processed data address (e.g. $3512). This is where the commutation position address Ixx83 will be pointing to. Also, this will be used in setting up the power-on phasing routine.

The commutation enable, and position address would then be:

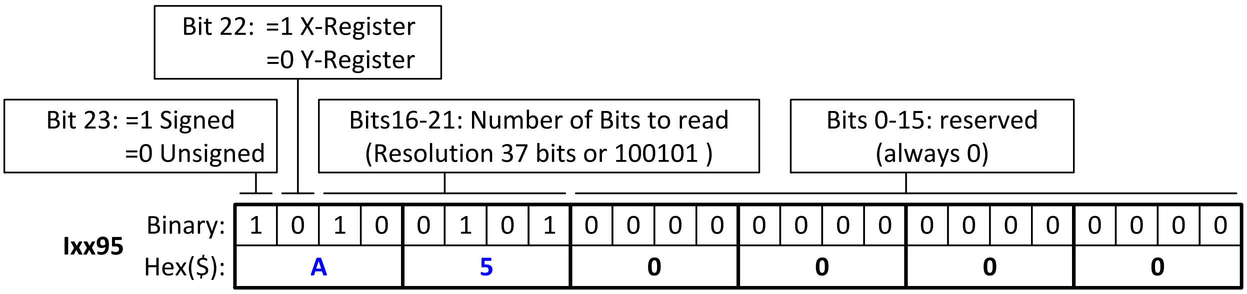
```
I101=1                 ; Mtr#1 Commutation enable, from X Register
I183=$3512             ; Mtr#1 Commutation Position Address –User Input
```

Absolute Power-On Position Read (Technique 2)

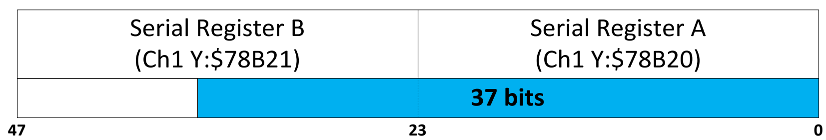
With technique 2, the absolute power-on position can be read directly from the serial data registers. But, proper scaling (5-bit right shift, in a PLC) is required to conform to the unshifted on-going position.

Example 1: Channel 1 driving a 37-bit (25-bit single turn, 12-bit multi-turn) rotary serial encoder:

```
I180=0                          ; Absolute power-on read disabled
I110=$78B20                     ; Absolute power-on position address (ch1 serial data register A)
I195=$A50000                    ; Parallel Read, 37 bits, Signed, from Y-Register -User Input
```



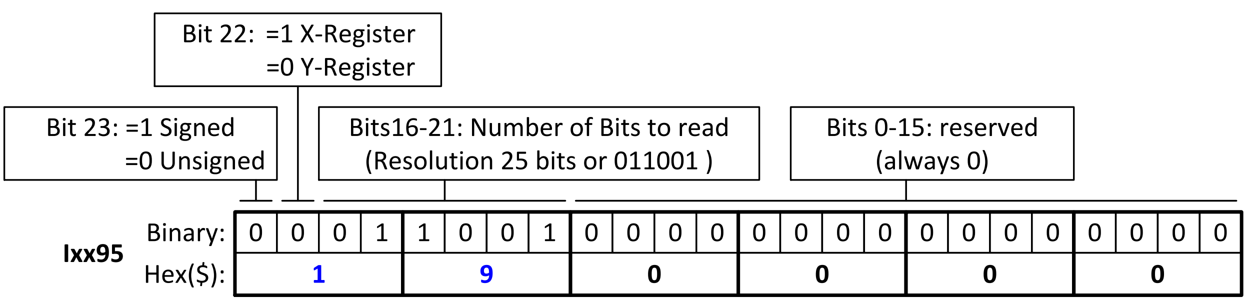
In this mode, PMAC reads 37 bits from the consecutive serial data registers:



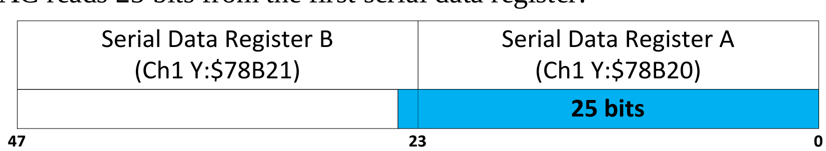
With the setting of Ixx80=0, the actual position is not reported automatically on power-up. It will be reported after scaling (i.e. in PLC, below).

Example 2: Channel 1 driving a 25-bit (25-bit Singleturn, No Multiturn) absolute rotary serial encoder, or a similar protocol resolution (25 bits) linear scale:

```
I180=0                          ; Absolute power-on read disabled
I110=$78B20                     ; Absolute power-on position address (ch1 serial data register A)
I195=$190000                    ; Parallel Read, 25 bits, Unsigned, from Y-Register -User Input
```



In this mode, PMAC reads 25 bits from the first serial data register:



With the setting of Ixx80=0, the actual position is not reported automatically on power-up. It will be reported after scaling (i.e. in PLC, below).

Note

With absolute serial encoders (no multi-turn data), the power-on position format is set up for unsigned operation.

Note

The upper two fields in Ixx95 are the only relevant ones. Bits 0 through 15 are reserved and should always be set to 0.

Power-On Position scaling PLC example (for technique 2)

```
M162->D:$00008B                             ; #1 Actual position (Suggested M-Variable)

Open PLC 1 clear
I5111=100*8388608/I10 while(I5111>0) endw   ; 100 msec delay
CMD"#1K"                                    ; Make sure motor(s) killed
I5111=100*8388608/I10 while(I5111>0) endw   ; 100 msec delay
CMD"#1$*"                                   ; Read un-scaled absolute position
I5111=100*8388608/I10 while(I5111>0) endw   ; 100 msec delay
M162=M162/32                                ; Scale absolute position (shift right 5 bits)
I5111=100*8388608/I10 while(I5111>0) endw   ; 100 msec delay
Dis PLC 1                                   ; Run once on power-up or reset
Close
```

Note

Some serial encoders use an external (not from the Brick) source for power. Make sure that this power is applied prior to performing an absolute read on power-up.

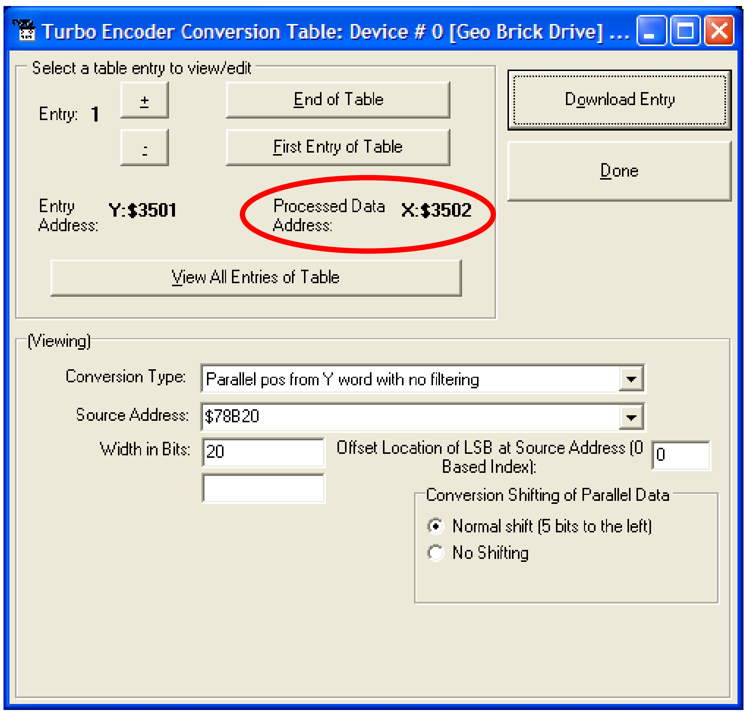
Technique 3 Example

Channel 1 is driving a 32-bit (20-bit Singleturn, 12-bit Multiturn) rotary serial encoder, or a linear scale with similar protocol resolution (20 bits, 0.1 micron).

Encoder Conversion Table - for position (Technique 3)

- Conversion Type: Parallel pos from Y word with no filtering
- Width in Bits: Singleturn/absolute resolution in bits (e.g. 20 bits)
- Offset Location of LSB: leave at zero
- Normal Shift (5 bits to the left)
- Source Address : serial data register A (see table below)
- Remember to click on Download Entry for the changes to take effect.

	Source Address (serial data register A)		
Channel 1	Y:$78B20	**Channel 5**	Y:$78B30
Channel 2	Y:$78B24	**Channel 6**	Y:$78B34
Channel 3	Y:$78B28	**Channel 7**	Y:$78B38
Channel 4	Y:$78B2C	**Channel 8**	Y:$78B3C



This is a 2-line ECT entry, its equivalent script code:

```
I8000=$278B20           ; Unfiltered parallel pos of location Y:$78B20
I8001=$014000           ; Width and Offset. Processed result at $3502
```

Typically, the position and velocity pointers are set to the processed data address (e.g. $3502). With Singleturn or linear resolutions less than 20 bits, the position/velocity scale factors, and position error limit can be left at default values. But with resolutions of 20 bits or greater, it is recommended to set the scale factors to 1 and the position error limit to its maximum value:

```
I100=1                  ; Mtr#1 Active. Remember to activate the channel to see feedback
I103=$3502              ; Mtr#1 position loop feedback address
I104=$3502              ; Mtr#1 velocity loop feedback address
I108=1                  ; Mtr#1 position-loop scale factor
I109=1                  ; Mtr#1 velocity-loop scale factor
I167=8388607            ; Mtr#1 Position Error Limit
```

Note

At this point, you should be able to move the motor/encoder shaft by hand and see 'motor' counts in the position window.

Counts Per User Units (Technique 3)

With technique 3, the user should expect to see 2^{ST} counts per revolution for rotary encoders, and 1/Resolution counts per user unit for linear scales in the motor position window.

Examples: 32-bit rotary encoder (20-bit Singleturn): 2^{20}= 1,048,576 cts/rev
0.1-micron linear scale: 1/0.0001= 10,000 cts/mm

Encoder Conversion Table - for commutation (Technique 3)

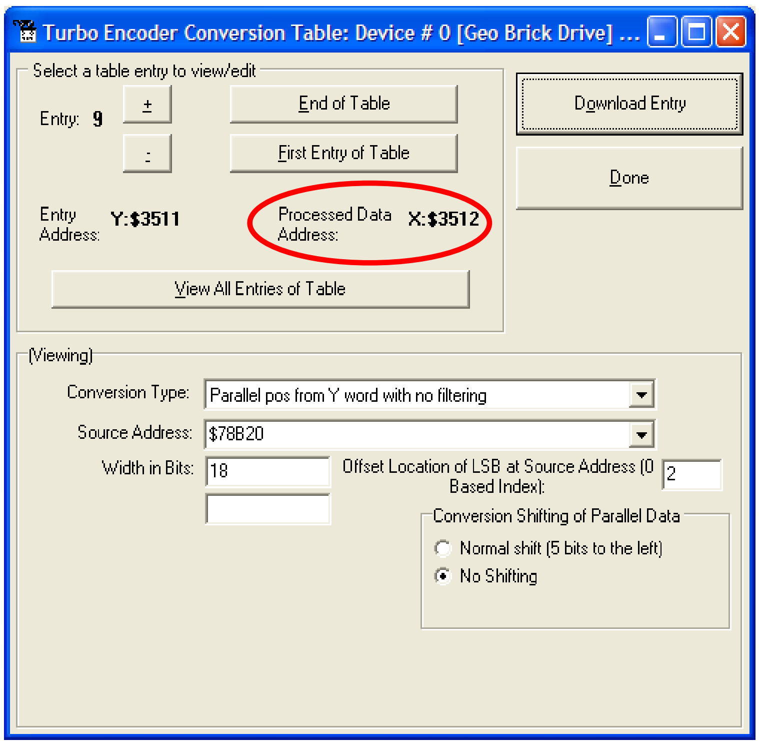
Commutation with Turbo PMAC does not require high resolution data. With Technique 3, it is recommended to fix it at 18 bits. This will also eliminate quantization noise.

Note

It is recommended to insert the commutation ECT entries after all of the position ECT entries have been configured.

Assuming that eight encoders have been configured for position, the first ECT for commutation for the first motor would be at entry number nine:

- Conversion Type: Parallel pos from Y word with no filtering
- Width in Bits: 18
- Offset Location of LSB = Singleturn/protocol bits – 18 (e.g. 20-18=2)
- No shifting
- Source Address: Serial data register A (same as position ECT for this motor)
- Remember to click on Download Entry for the changes to take effect.



This is a 2-line ECT entry, its equivalent script code:

```
I8016=$2F8B20           ; Unfiltered parallel pos of location Y:$78B20 -User Input
I8017=$12002            ; Width and Offset. Processed result at X:$3512 -User Input
```

Note

Record the processed data address (e.g. $3512). This is where the commutation position address Ixx83 will be pointing to. Also, this will be used in setting up the power-on phasing routine.

The commutation enable, and position address would then be:

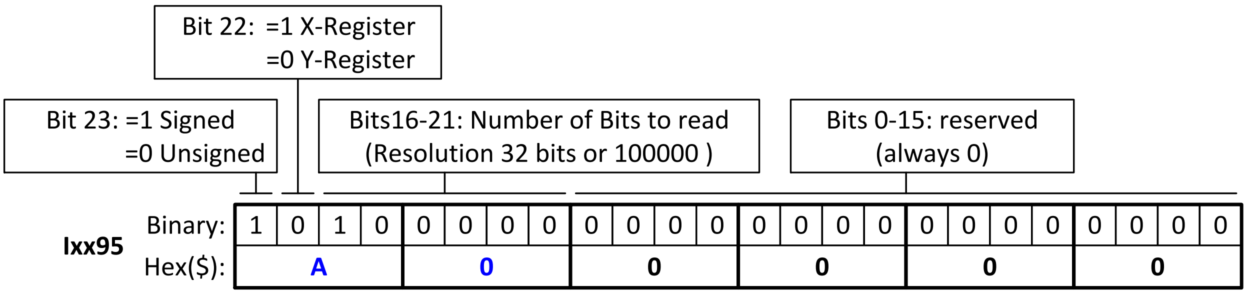
```
I101=1                  ; Mtr#1 Commutation enable, from X Register
I183=$3512              ; Mtr#1 Commutation Position Address -User Input
```

Absolute Power-On Position Read (Technique 3)

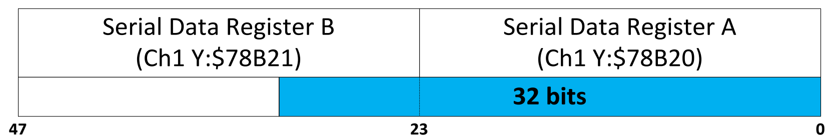
With Technique 3, the absolute power-on read can be performed using PMAC's automatic settings (Ixx80, Ixx10 and Ixx95).

Example 1: Channel 1 driving a 32-bit (20-bit single turn, 12-bit multi-turn) rotary serial encoder:

```
I180=2                         ; Absolute power-on read enabled
I110=$78B20                    ; Absolute power-on position address (ch1 serial data register A)
I195=$A00000                   ; Parallel Read, 32 bits, Signed, from Y-Register -User Input
```



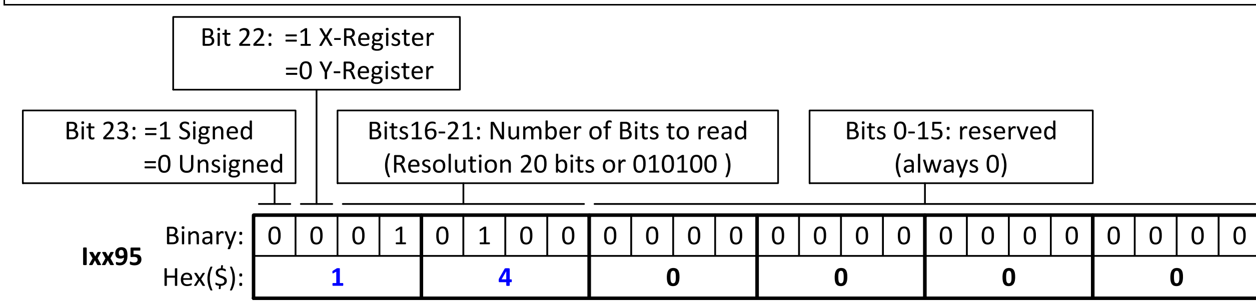
In this mode, PMAC reads and reports 32 bits from the consecutive serial data registers:



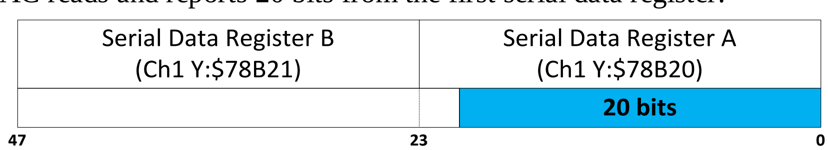
With the setting of Ixx80=2, the actual position is reported automatically on Power-up. Otherwise, a #1$* command is necessary to read and report the absolute position.

Example 2: Channel 1 driving a 20-bit (20-bit Singleturn, No Multiturn) absolute rotary serial encoder, or a similar protocol resolution (20 bits) linear scale:

```
I180=2                         ; Absolute power-on read enabled
I110=$78B20                    ; Absolute power-on position address (ch1 serial data register A)
I195=$140000                   ; Parallel Read, 20 bits, Unsigned, from Y-Register -User Input
```



In this mode, PMAC reads and reports 20 bits from the first serial data register:



With the setting of Ixx80=2, the actual position is reported automatically on Power-up. Otherwise, a #1$* command is necessary to read and report the absolute position.

Note

With absolute serial encoders (no multi-turn data), the power-on position format is set up for unsigned operation.

Note

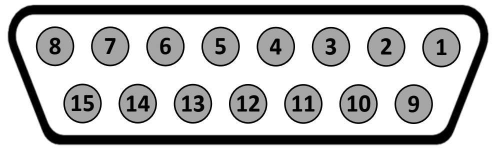
The upper two fields in Ixx95 are the only relevant ones. Bits 0 through 15 are reserved and should always be set to 0.

Note

Some serial encoders use an external (not from the Brick) source for power. Make sure that this power is applied prior to performing an absolute read on power-up.

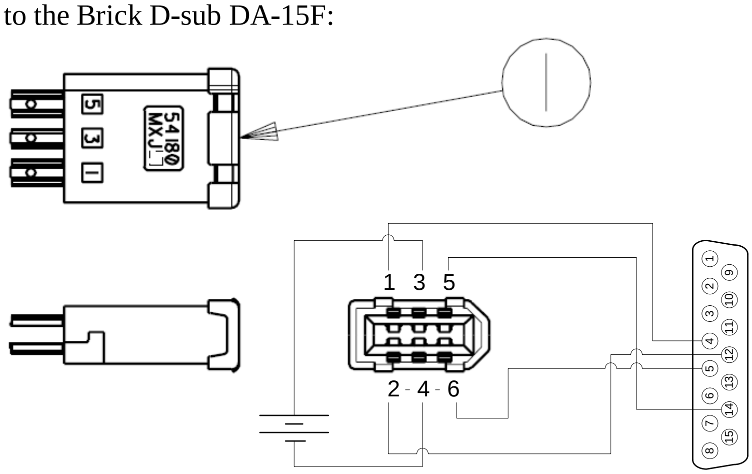
X1-X8: Encoder Feedback, Yaskawa Sigma II & III

X1-X8: D-sub DA-15F
Mating: D-sub DA-15M

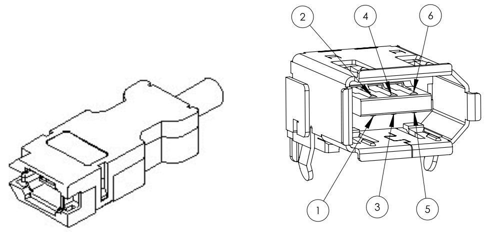


Pin #	Symbol	Function	Notes
1			
2			
3			
4	EncPwr	Output	Encoder Power 5 Volts
5	SDI	Input	Serial Data In
6			
7			
8			
9			
10			
11			
12	GND	Common	Common Ground
13			
14	SDO	Output	Serial Data Out
15			

If you prefer to keep the original Molex connector on the Yaskawa encoder cable, the following converter can be used to attach to the Brick D-sub DA-15F:



Yaskawa Encoder Cable has FEMALE Connector by defalut



Molex 2.00 mm (.079") Pitch Serial I/O Connector, Receptacle Kit, Wire-to-Wire.
Part Number: 0542800609

Pin #	Function	Wire Color code
1	+5VDC	RED
2	GND	BLACK
3	BAT+	Orange
4	BAT-	Orange/Black (Orange/White)
5	SDO	Blue
6	SDI	Blue/Black (Blue/White)

Note

All Yaskawa Sigma II & Sigma III protocols, whether incremental or absolute and regardless of the resolution, are supported.

This option allows the Brick to connect to up to eight Yaskawa devices. Setting up the Yaskawa Sigma interface correctly requires the programming of two essential control registers:

- Global Control Registers
- Channel Control Registers

The resulting data is found in:

- Yaskawa Data Registers

Global Control Registers

X:$78BnF (default value: $002003)   where n=2 for axes 1-4
n=3 for axes 5-8

	Global Control Register
Axes 1-4	X:$78B2F
Axes 5-8	X:$78B3F

Note

With the Yaskawa option, the Global Control Register is pre-set and need not be changed.

[23-16]								[15-12]				11	10	9	8	7	6	5	4	3	2	1	0
M Divisor								N Divisor				Reserved		Trig. Clock	Trig. Edge	Trigger Delay				Protocol Code			
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
0				0				0				0				0				6			

Bit	Type	Default	Name	Description
[23:16]	R/W	0x00	M_Divisor	Intermediate clock frequency for SER_Clock. The intermediate clock is generated from a (M+1) divider clocked at 100 MHz.
[15:12]	R/W	0x0	N_Divisor	Final clock frequency for SER_Clock. The final clock is generated from a 2^N divider clocked by the intermediate clock.
[11:10]	R	00	Reserved	Reserved and always reads zero.
[09]	R/W	0	TriggerClock	Trigger clock select for initiating serial encoder communications: 0= PhaseClock 1= ServoClock
[08]	R/W	0	TriggerEdge	Active clock edge select for the trigger clock: 0= rising edge 1= falling edge
[07:04]	R/W	0x0	TriggerDelay	Trigger delay program relative to the active edge of the trigger clock. Units are in increments of 20 usec.
[03:00]	R		ProtocolCode	This read-only bit field is used to read the serial interface protocol supported by the FPGA. A value of $5 defines this protocol as Yaskawa Sigma I. A value of $6 defines this protocol as Yaskawa Sigma II.

Channel Control Registers

X:$78Bn0, X:$78Bn4, X:$78Bn8, X:$78BnC where: n=2 for axes 1-4
n=3 for axes 5-8

Channel 1	X:$78B20	**Channel 5**	X:$78B20
Channel 2	X:$78B24	**Channel 6**	X:$78B34
Channel 3	X:$78B28	**Channel 7**	X:$78B38
Channel 4	X:$78B2C	**Channel 8**	X:$78B3C

Bits 10, 12, and 13 are the only fields to be configured in the Channel Control Registers with the Yaskawa option. The rest is protocol information. This has to be done in a startup PLC to execute once on power up.

[23:14]	13	12	11	10	[9:0]
Reserved	Trig. Mode	Trig. Enable		RxData Ready/ SENC	Reserved

Bit	Type	Default	Name	Description
[23:14]	R	0x000	Reserved	Reserved and always reads zero.
[13]	R/W	0	Trigger Mode	Trigger Mode to initiate communication: 0= continuous trigger 1= one-shot trigger All triggers occur at the defined Phase/Servo clock edge and delay setting. See Global Control register for these settings.
[12]	R/W	0	Trigger Enable	Enable trigger for serial encoder communications: 0= disabled 1= enabled This bit must be set for either trigger mode. If the Trigger Mode bit is set for one-shot mode, the hardware will automatically clear this bit after the trigger occurs.
[11]	R/W	0	Reserved	Reserved and always reads zero.
[10]	R	0	RxData Ready	This read-only bit provides the received data status. It is low while the interface logic is communicating (busy) with the serial encoder. It is high when all the data has been received and processed.
	W	0	SENC_MODE	This write-only bit is used to enable the output drivers for the SENC_SDO, SENC_CLK, SENC_ENA pins for each respective channel. It also directly drives the respective SENC_MODE pin for each channel.
[09:00]	R	0x0	Reserved	Reserved and always reads zero.

Yaskawa Feedback Channel Control Power-On Example PLC (Motors 1-8)

This code statement can be added to your existing initialization PLC.

```
Open PLC 1 clear
CMD"WX:$78B20,$1400"
CMD"WX:$78B24,$1400"
CMD"WX:$78B28,$1400"
CMD"WX:$78B2C,$1400"
CMD"WX:$78B30,$1400"
CMD"WX:$78B34,$1400"
CMD"WX:$78B38,$1400"
CMD"WX:$78B3C,$1400"
Disable plc 1
Close
```

Yaskawa Data Registers

Yaskawa Data Registers			
Channel 1	Y:$78B20	Channel 5	Y:$78B30
Channel 2	Y:$78B24	Channel 6	Y:$78B34
Channel 3	Y:$78B28	Channel 7	Y:$78B38
Channel 4	Y:$78B2C	Channel 8	Y:$78B3C

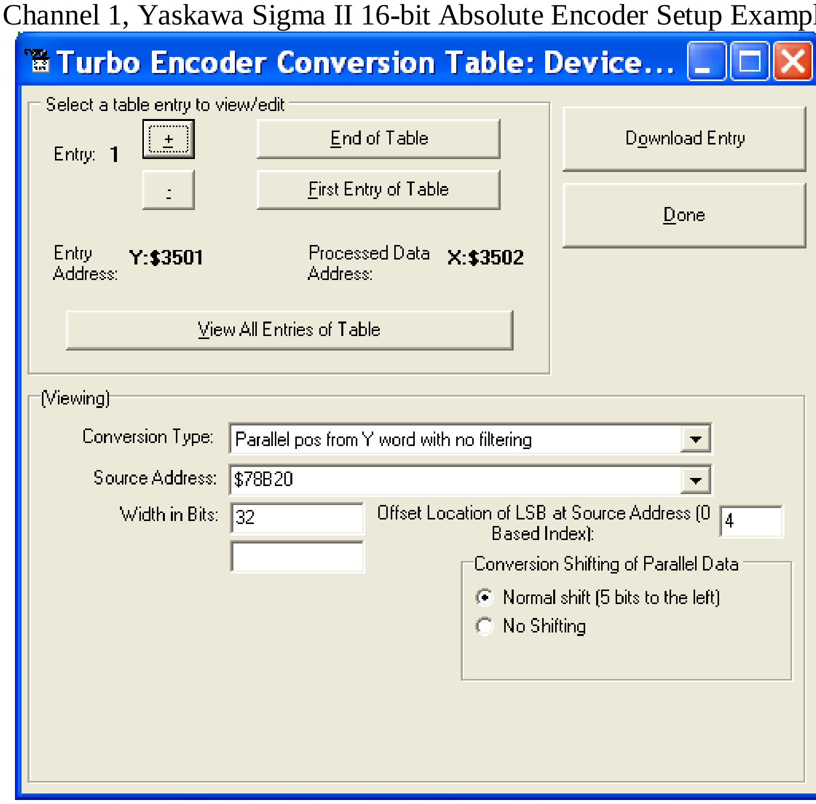
Yaskawa Sigma II 16-Bit Absolute Encoder

Y:$78B21		Y:$78B20		
[23-12]	[11-0]	[23-20]	[19-4]	[3:0]
	Multi-Turn Position (16-bits)		Absolute Single Turn Data (16-bits)	

Yaskawa Data Registers			
Channel 1	Y:$78B20	Channel 5	Y:$78B30
Channel 2	Y:$78B24	Channel 6	Y:$78B34
Channel 3	Y:$78B28	Channel 7	Y:$78B38
Channel 4	Y:$78B2C	Channel 8	Y:$78B3C

The on-going servo and commutation position data is setup using a 2-line Entry in the Encoder Conversion Table. The first line represents a Parallel Y-Word with no filtering ($2) from the corresponding Yaskawa data register/channel. The second line represents the width of the data to be read and bit location of the LSB of the data in the source word.

Channel 1, Yaskawa Sigma II 16-bit Absolute Encoder Setup Example



Encoder Conversion Table Setup (Motors 1-8)

The ECT automatic entry is equivalent to:

```
I8000=$278B20  ; Entry 1 Unfiltered parallel pos of location Y:$78B20
I8001=$020004  ; Width and Bias, total of 32-bits LSB starting at bit#4

I8002=$278B24  ; Entry 2 Unfiltered parallel pos of location Y:$78B24
I8003=$020004  ; Width and Bias, total of 32-bits LSB starting at bit#4

I8004=$278B28  ; Entry 3 Unfiltered parallel pos of location Y:$78B28
I8005=$020004  ; Width and Bias, total of 32-bits LSB starting at bit#4
```

```
I8006=$278B2C  ; Entry 4 Unfiltered parallel pos of location Y:$78B2C
I8007=$020004  ; Width and Bias, total of 32-bits LSB starting at bit#4

I8008=$278B30  ; Entry 5 Unfiltered parallel pos of location Y:$78B30
I8009=$020004  ; Width and Bias, total of 32-bits LSB starting at bit#4

I8010=$278B34  ; Entry 6 Unfiltered parallel pos of location Y:$78B34
I8011=$020004  ; Width and Bias, total of 32-bits LSB starting at bit#4

I8012=$278B38  ; Entry 7 Unfiltered parallel pos of location Y:$78B38
I8013=$020004  ; Width and Bias, total of 32-bits LSB starting at bit#4

I8014=$278B3C  ; Entry 8 Unfiltered parallel pos of location Y:$78B3C
I8015=$020004  ; Width and Bias, total of 32-bits LSB starting at bit#4
```

Position (Ixx03) and Velocity (Ixx04) Pointers

```
I103=$3502     ; Motor 1 Position feedback address, ECT processed data
I104=$3502     ; Motor 1 Velocity feedback address, ECT processed data
I203=$3504     ; Motor 2 Position feedback address, ECT processed data
I204=$3504     ; Motor 2 Velocity feedback address, ECT processed data
I303=$3506     ; Motor 3 Position feedback address, ECT processed data
I304=$3506     ; Motor 3 Velocity feedback address, ECT processed data
I403=$3508     ; Motor 4 Position feedback address, ECT processed data
I404=$3508     ; Motor 4 Velocity feedback address, ECT processed data
I503=$350A     ; Motor 5 Position feedback address, ECT processed data
I504=$350A     ; Motor 5 Velocity feedback address, ECT processed data
I603=$350C     ; Motor 6 Position feedback address, ECT processed data
I604=$350C     ; Motor 6 Velocity feedback address, ECT processed data
I703=$350E     ; Motor 7 Position feedback address, ECT processed data
I704=$350E     ; Motor 7 Velocity feedback address, ECT processed data
I803=$3510     ; Motor 8 Position feedback address, ECT processed data
I804=$3510     ; Motor 8 Velocity feedback address, ECT processed data
```

Motor Activation

```
I100,8,100=1   ; Motors 1-8 Activated
```

Note

At this point, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window.

Absolute Power-On Position Read (Yaskawa 16-bit)

Channel 1 example PLC, 16-bit Absolute Sigma II Encoder

```
End Gat
Del Gat
Close

#define STD0_15        M7000  ; Single-turn Data 0-15 (16-bits)
#define MTD0_3         M7001  ; Multi-Turn Data 0-3 (4-bits)
#define MTD4_15        M7002  ; Multi-Turn Data 4-15 (12-bits)
#define MTD0_15        M7003  ; Multi-Turn Data 0-15 (16-bits)

STD0_15->Y:$78B20,4,16
MTD0_3->Y:$78B20,20,4
MTD4_15->Y:$78B21,0,12
MTD0_15->*

#define Mtr1ActPos      M162
Mtr1ActPos->D:$00008B ; #1 Actual position (1/[Ixx08*32] cts)

Open plc 1 clear
MTD0_15 = MTD4_15 * $10 + MTD0_3
If (MTD0_15>$7FFF)
       MTD0_15 = (MTD0_15^$FFFF + 1)*-1
       If (STD0_15 !=0)
              STD0_15 = (STD0_15^$FFFF + 1)*-1
       Endif
Endif
Mtr1ActPos = ((MTD0_15 * $10000)+ STD0_15) * I108 * 32
disable plc 1
close
```

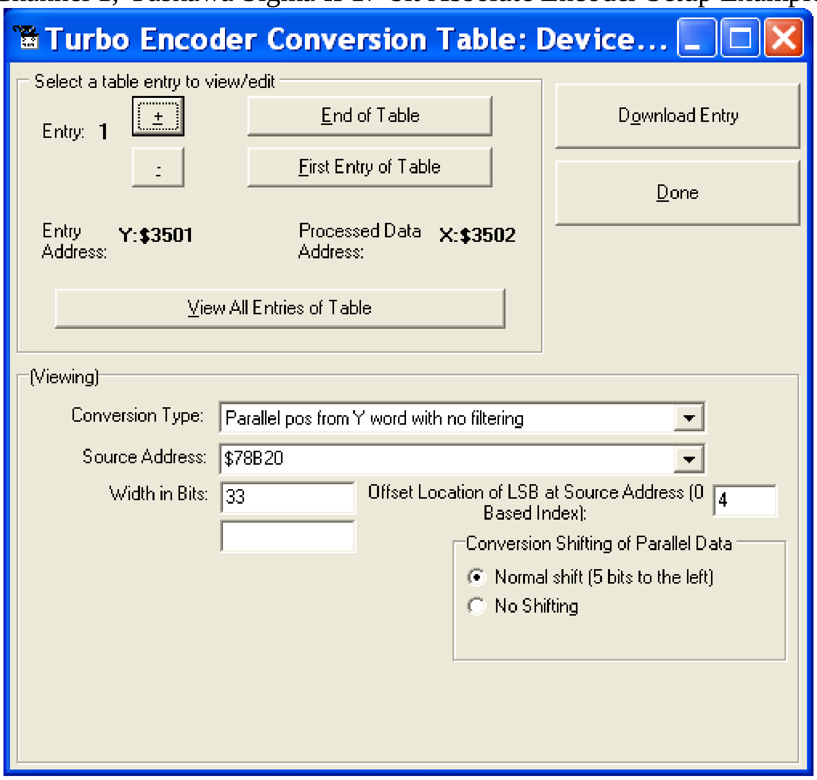
Yaskawa Sigma II 17-Bit Absolute Encoder

Y:$78B21		Y:$78B20		
[23-13]	[12-0]	[23-21]	[20-4]	[3:0]
	Multi-Turn Position (16-bits)		Absolute Single Turn Data (17-bits)	

Yaskawa Data Registers			
Channel 1	Y:$78B20	Channel 5	Y:$78B30
Channel 2	Y:$78B24	Channel 6	Y:$78B34
Channel 3	Y:$78B28	Channel 7	Y:$78B38
Channel 4	Y:$78B2C	Channel 8	Y:$78B3C

The on-going servo and commutation position data is setup using a 2-line Entry in the Encoder Conversion Table. The first line represents a Parallel Y-Word with no filtering ($2) from the corresponding Yaskawa data register/channel. The second line represents the width of the data to be read and bit location of the LSB of the data in the source word.

Channel 1, Yaskawa Sigma II 17-bit Absolute Encoder Setup Example



Encoder Conversion Table Setup (Motors 1-8)

The ECT automatic entry is equivalent to:

```
I8000=$278B20  ; Entry 1 Unfiltered parallel pos of location Y:$78B20
I8001=$021004  ; Width and Bias, total of 33-bits LSB starting at bit#4

I8002=$278B24  ; Entry 2 Unfiltered parallel pos of location Y:$78B24
I8003=$021004  ; Width and Bias, total of 33-bits LSB starting at bit#4

I8004=$278B28  ; Entry 3 Unfiltered parallel pos of location Y:$78B28
I8005=$021004  ; Width and Bias, total of 33-bits LSB starting at bit#4

I8006=$278B2C  ; Entry 4 Unfiltered parallel pos of location Y:$78B2C
I8007=$021004  ; Width and Bias, total of 33-bits LSB starting at bit#4

I8008=$278B30  ; Entry 5 Unfiltered parallel pos of location Y:$78B30
I8009=$021004  ; Width and Bias, total of 33-bits LSB starting at bit#4

I8010=$278B34  ; Entry 6 Unfiltered parallel pos of location Y:$78B34
I8011=$021004  ; Width and Bias, total of 33-bits LSB starting at bit#4

I8012=$278B38  ; Entry 7 Unfiltered parallel pos of location Y:$78B38
I8013=$021004  ; Width and Bias, total of 33-bits LSB starting at bit#4

I8014=$278B3C  ; Entry 8 Unfiltered parallel pos of location Y:$78B3C
I8015=$021004  ; Width and Bias, total of 33-bits LSB starting at bit#4
```

Position (Ixx03) and Velocity (Ixx04) Pointers

```
I103=$3502     ; Motor 1 Position feedback address, ECT processed data
I104=$3502     ; Motor 1 Velocity feedback address, ECT processed data
I203=$3504     ; Motor 2 Position feedback address, ECT processed data
I204=$3504     ; Motor 2 Velocity feedback address, ECT processed data
I303=$3506     ; Motor 3 Position feedback address, ECT processed data
I304=$3506     ; Motor 3 Velocity feedback address, ECT processed data
I403=$3508     ; Motor 4 Position feedback address, ECT processed data
I404=$3508     ; Motor 4 Velocity feedback address, ECT processed data
I503=$350A     ; Motor 5 Position feedback address, ECT processed data
I504=$350A     ; Motor 5 Velocity feedback address, ECT processed data
I603=$350C     ; Motor 6 Position feedback address, ECT processed data
I604=$350C     ; Motor 6 Velocity feedback address, ECT processed data
I703=$350E     ; Motor 7 Position feedback address, ECT processed data
I704=$350E     ; Motor 7 Velocity feedback address, ECT processed data
I803=$3510     ; Motor 8 Position feedback address, ECT processed data
I804=$3510     ; Motor 8 Velocity feedback address, ECT processed data
```

Motor Activation

```
I100,8,100=1   ; Motors 1-8 Activated
```

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window.

Absolute Power-On Position Read (Yaskawa 17-bit)

Channel 1 example PLC, 17-bit Absolute Sigma II Encoder

```
End Gat
Del Gat
Close

#define FirstWord       M7000 ; Yaskawa Data Register1, 1st word
#define SecondWord      M7001 ; Yaskawa Data Register1, 2nd word
#define STD0_16         M7002 ; Single-Turn Data 0-16 (17-bits)
#define MTD0_15         M7003 ; Multi-Turn Data 0-15 (16-bits)

FirstWord->Y:$78B20,0,24
SecondWord->Y:$78B21,0,4
STD0_16->*
MTD0_15->*

#define Mtr1ActPos      M162
Mtr1ActPos->D:$00008B ; #1 Actual position (1/[Ixx08*32] cts)

open plc 1 clear
MTD0_15 = (SecondWord & $1FFF) * $8 + int (FirstWord / 2097152)
STD0_16 = int ((FirstWord & $1FFFF0) / 16)
If (MTD0_15>$7FFF)
        MTD0_15 = (MTD0_15^$FFFF + 1)*-1

        If (STD0_16 !=0)
                STD0_16 = (STD0_16^$1FFFF + 1)*-1
        Endif
Endif
Mtr1ActPos = ((MTD0_15 * $20000)+ STD0_16) * I108 * 32
disable plc 1
close
```

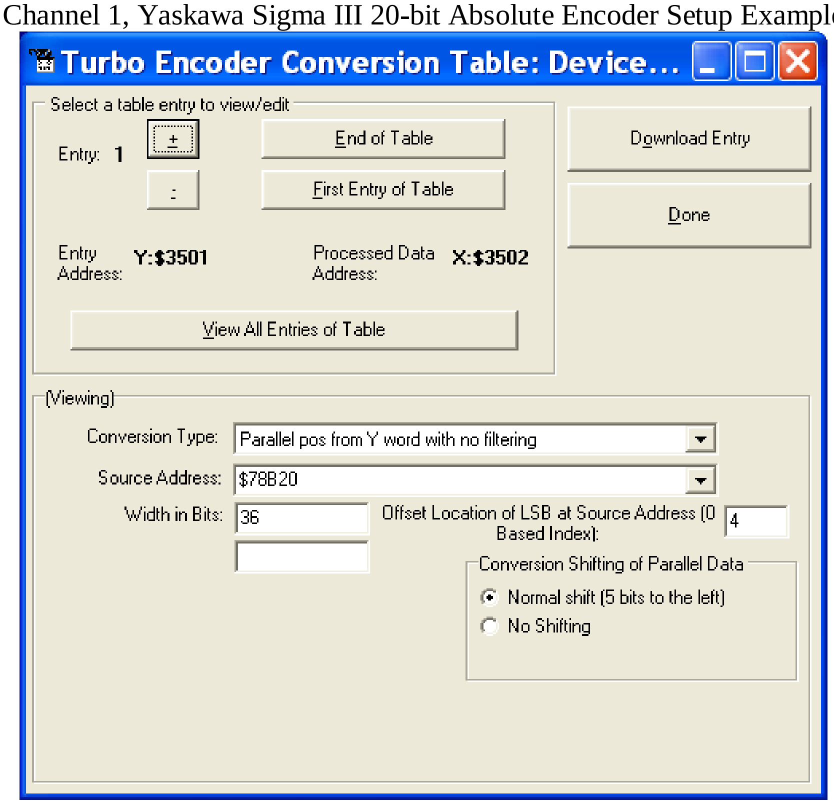
Yaskawa Sigma III 20-Bit Absolute Encoder

Y:$78B21		Y:$78B20	
[23-16]	[15-0]	[23-4]	[3:0]
	Multi-Turn Position (16-bits)	Absolute Single Turn Data (20-bits)	

Yaskawa Data Registers			
Channel 1	Y:$78B20	Channel 5	Y:$78B30
Channel 2	Y:$78B24	Channel 6	Y:$78B34
Channel 3	Y:$78B28	Channel 7	Y:$78B38
Channel 4	Y:$78B2C	Channel 8	Y:$78B3C

The on-going servo and commutation position data is setup using a 2-line Entry in the Encoder Conversion Table. The first line represents a Parallel Y-Word with no filtering ($2) from the corresponding Yaskawa data register/channel. The second line represents the width of the data to be read and bit location of the LSB of the data in the source word.

Channel 1, Yaskawa Sigma III 20-bit Absolute Encoder Setup Example



Encoder Conversion Table Setup (Motors 1-8)

The ECT automatic entry is equivalent to:

```
I8000=$278B20  ; Entry 1 Unfiltered parallel pos of location Y:$78B20
I8001=$024004  ; Width and Bias, total of 36-bits LSB starting at bit#4

I8002=$278B24  ; Entry 2 Unfiltered parallel pos of location Y:$78B24
I8003=$024004  ; Width and Bias, total of 36-bits LSB starting at bit#4

I8004=$278B28  ; Entry 3 Unfiltered parallel pos of location Y:$78B28
I8005=$024004  ; Width and Bias, total of 36-bits LSB starting at bit#4

I8006=$278B2C  ; Entry 4 Unfiltered parallel pos of location Y:$78B2C
I8007=$024004  ; Width and Bias, total of 36-bits LSB starting at bit#4

I8008=$278B30  ; Entry 5 Unfiltered parallel pos of location Y:$78B30
I8009=$024004  ; Width and Bias, total of 36-bits LSB starting at bit#4

I8010=$278B34  ; Entry 6 Unfiltered parallel pos of location Y:$78B34
I8011=$024004  ; Width and Bias, total of 36-bits LSB starting at bit#4

I8012=$278B38  ; Entry 7 Unfiltered parallel pos of location Y:$78B38
I8013=$024004  ; Width and Bias, total of 36-bits LSB starting at bit#4

I8014=$278B3C  ; Entry 8 Unfiltered parallel pos of location Y:$78B3C
I8015=$024004  ; Width and Bias, total of 36-bits LSB starting at bit#4
```

Position (Ixx03) and Velocity (Ixx04) Pointers

```
I103=$3502     ; Motor 1 Position feedback address, ECT processed data
I104=$3502     ; Motor 1 Velocity feedback address, ECT processed data
I203=$3504     ; Motor 2 Position feedback address, ECT processed data
I204=$3504     ; Motor 2 Velocity feedback address, ECT processed data
I303=$3506     ; Motor 3 Position feedback address, ECT processed data
I304=$3506     ; Motor 3 Velocity feedback address, ECT processed data
I403=$3508     ; Motor 4 Position feedback address, ECT processed data
I404=$3508     ; Motor 4 Velocity feedback address, ECT processed data
I503=$350A     ; Motor 5 Position feedback address, ECT processed data
I504=$350A     ; Motor 5 Velocity feedback address, ECT processed data
I603=$350C     ; Motor 6 Position feedback address, ECT processed data
I604=$350C     ; Motor 6 Velocity feedback address, ECT processed data
I703=$350E     ; Motor 7 Position feedback address, ECT processed data
I704=$350E     ; Motor 7 Velocity feedback address, ECT processed data
I803=$3510     ; Motor 8 Position feedback address, ECT processed data
I804=$3510     ; Motor 8 Velocity feedback address, ECT processed data
```

Motor Activation

```
I100,8,100=1   ; Motors 1-8 Activated
```

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window.

Absolute Power-On Position Read (Yaskawa 20-bit)

Channel 1 example PLC, 20-bit Absolute Sigma III Encoder

```
End Gat
Del Gat
Close

#define FirstWord       M1000 ; Yaskawa Data Register1, 1st word
#define SecondWord      M1001 ; Yaskawa Data Register1, 2nd word
#define STD0_19         M1002 ; Single-Turn Data 0-19 (20-bits)
#define MTD0_15         M1003 ; Multi-Turn Data 0-15 (16-bits)

FirstWord->Y:$78B20,0,24
SecondWord->Y:$78B21,0,4
STD0_19->*
MTD0_15->*

#define Mtr1ActPos      M162
Mtr1ActPos->D:$00008B ; #1 Actual position (1/[Ixx08*32] cts)

open plc 1 clear
MTD0_15 = (SecondWord & $FFFF)
STD0_19 = int ((FirstWord & $FFFFF0) / 16)
If (MTD0_15>$7FFF)
       MTD0_15 = (MTD0_15^$FFFF + 1)*-1

       If (STD0_19 !=0)
              STD0_19 = (STD0_19^$FFFFF + 1)*-1
       Endif
Endif
Mtr1ActPos = ((MTD0_15 * $100000)+ STD0_19) * I108 * 32
disable plc 1
close
```

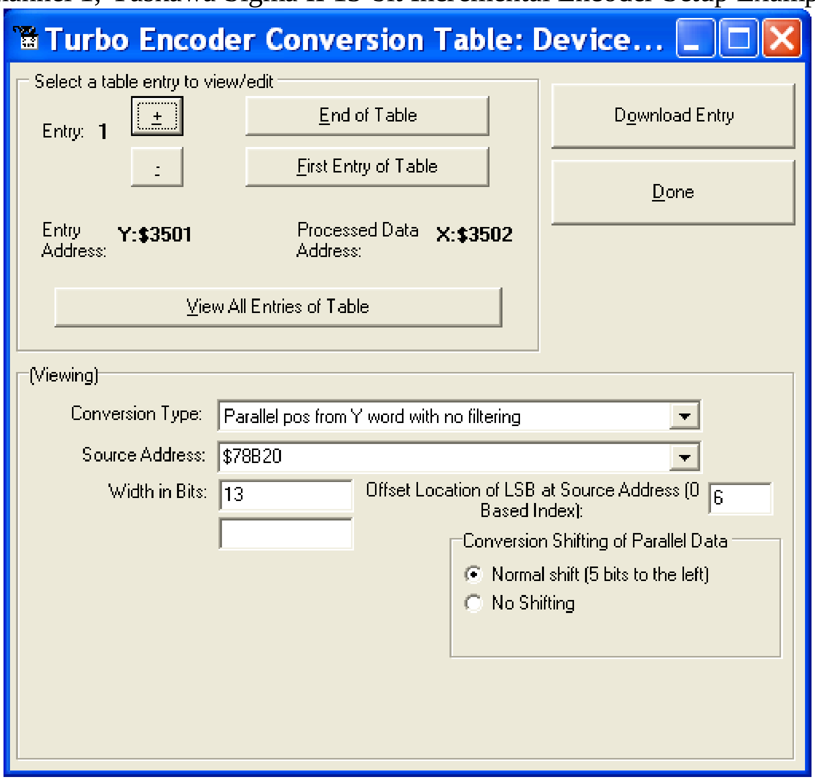
Yaskawa Sigma II 13-Bit Incremental Encoder

Y:$78B21		Y:$78B20						
[23-11]	[10-0]	23	[22-11]	[10:4]	3	2	1	0
	Incremental Compensation (11-bits)		Incremental Position in Single Turn (13-bits)		U	V	W	Z

Yaskawa Data Registers			
Channel 1	Y:$78B20	Channel 5	Y:$78B30
Channel 2	Y:$78B24	Channel 6	Y:$78B34
Channel 3	Y:$78B28	Channel 7	Y:$78B38
Channel 4	Y:$78B2C	Channel 8	Y:$78B3C

The on-going servo and commutation position data is setup using a 2-line Entry in the Encoder Conversion Table. The first line represents a Parallel Y-Word with no filtering ($2) from the corresponding Yaskawa data register/channel. The second line represents the width of the data to be read and bit location of the LSB of the data in the source word.

Channel 1, Yaskawa Sigma II 13-bit Incremental Encoder Setup Example



Encoder Conversion Table Setup (Motors 1-8)

The ECT automatic entry is equivalent to:

```
I8000=$278B20  ; Entry 1 Unfiltered parallel pos of location Y:$78B20
I8001=$00D006  ; Width and Bias, total of 13-bits LSB starting at bit#6

I8002=$278B24  ; Entry 2 Unfiltered parallel pos of location Y:$78B24
I8003=$00D006  ; Width and Bias, total of 13-bits LSB starting at bit#6

I8004=$278B28  ; Entry 3 Unfiltered parallel pos of location Y:$78B28
I8005=$00D006  ; Width and Bias, total of 13-bits LSB starting at bit#6

I8006=$278B2C  ; Entry 4 Unfiltered parallel pos of location Y:$78B2C
I8007=$00D006  ; Width and Bias, total of 13-bits LSB starting at bit#6

I8008=$278B30  ; Entry 5 Unfiltered parallel pos of location Y:$78B30
I8009=$00D006  ; Width and Bias, total of 13-bits LSB starting at bit#6

I8010=$278B34  ; Entry 6 Unfiltered parallel pos of location Y:$78B34
I8011=$00D006  ; Width and Bias, total of 13-bits LSB starting at bit#6

I8012=$278B38  ; Entry 7 Unfiltered parallel pos of location Y:$78B38
I8013=$00D006  ; Width and Bias, total of 13-bits LSB starting at bit#6

I8014=$278B3C  ; Entry 8 Unfiltered parallel pos of location Y:$78B3C
I8015=$00D006  ; Width and Bias, total of 13-bits LSB starting at bit#6
```

Position (Ixx03) and Velocity (Ixx04) Pointers

```
I103=$3502     ; Motor 1 Position feedback address, ECT processed data
I104=$3502     ; Motor 1 Velocity feedback address, ECT processed data
I203=$3504     ; Motor 2 Position feedback address, ECT processed data
I204=$3504     ; Motor 2 Velocity feedback address, ECT processed data
I303=$3506     ; Motor 3 Position feedback address, ECT processed data
I304=$3506     ; Motor 3 Velocity feedback address, ECT processed data
I403=$3508     ; Motor 4 Position feedback address, ECT processed data
I404=$3508     ; Motor 4 Velocity feedback address, ECT processed data
I503=$350A     ; Motor 5 Position feedback address, ECT processed data
I504=$350A     ; Motor 5 Velocity feedback address, ECT processed data
I603=$350C     ; Motor 6 Position feedback address, ECT processed data
I604=$350C     ; Motor 6 Velocity feedback address, ECT processed data
I703=$350E     ; Motor 7 Position feedback address, ECT processed data
I704=$350E     ; Motor 7 Velocity feedback address, ECT processed data
I803=$3510     ; Motor 8 Position feedback address, ECT processed data
I804=$3510     ; Motor 8 Velocity feedback address, ECT processed data
```

Motor Activation

```
I100,8,100=1   ; Motors 1-8 Activated
```

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window.

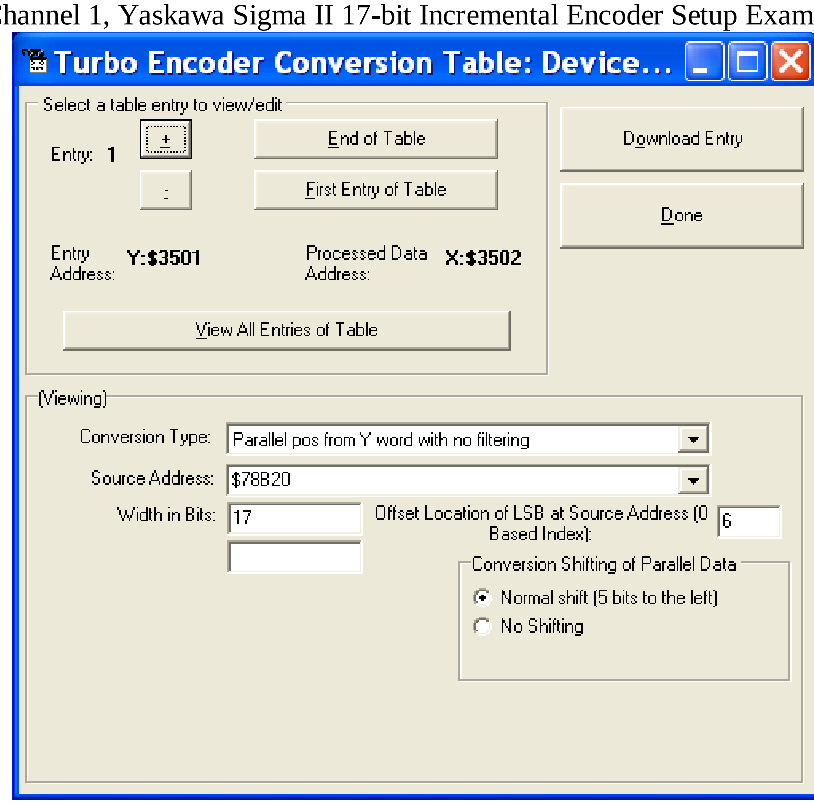
Yaskawa Sigma II 17-Bit Incremental Encoder

Y:$78B21		Y:$78B20						
[23-11]	[10-0]	23	[22-6]	[5:4]	3	2	1	0
	Incremental Compensation (11-bits)		Incremental Position in Single Turn (17-bits)		U	V	W	Z

Yaskawa Data Registers			
Channel 1	Y:$78B20	Channel 5	Y:$78B30
Channel 2	Y:$78B24	Channel 6	Y:$78B34
Channel 3	Y:$78B28	Channel 7	Y:$78B38
Channel 4	Y:$78B2C	Channel 8	Y:$78B3C

The on-going servo and commutation position data is setup using a 2-line Entry in the Encoder Conversion Table. The first line represents a Parallel Y-Word with no filtering ($2) from the corresponding Yaskawa data register/channel. The second line represents the width of the data to be read and bit location of the LSB of the data in the source word.

Channel 1, Yaskawa Sigma II 17-bit Incremental Encoder Setup Example



Encoder Conversion Table Setup (Motors 1-8)

The ECT automatic entry is equivalent to:

```
I8000=$278B20  ; Entry 1 Unfiltered parallel pos of location Y:$78B20
I8001=$011006  ; Width and Bias, total of 17-bits LSB starting at bit#6

I8002=$278B24  ; Entry 2 Unfiltered parallel pos of location Y:$78B24
I8003=$011006  ; Width and Bias, total of 17-bits LSB starting at bit#6

I8004=$278B28  ; Entry 3 Unfiltered parallel pos of location Y:$78B28
I8005=$011006  ; Width and Bias, total of 17-bits LSB starting at bit#6

I8006=$278B2C  ; Entry 4 Unfiltered parallel pos of location Y:$78B2C
I8007=$011006  ; Width and Bias, total of 17-bits LSB starting at bit#6

I8008=$278B30  ; Entry 5 Unfiltered parallel pos of location Y:$78B30
I8009=$011006  ; Width and Bias, total of 17-bits LSB starting at bit#6

I8010=$278B34  ; Entry 6 Unfiltered parallel pos of location Y:$78B34
I8011=$011006  ; Width and Bias, total of 17-bits LSB starting at bit#6

I8012=$278B38  ; Entry 7 Unfiltered parallel pos of location Y:$78B38
I8013=$011006  ; Width and Bias, total of 17-bits LSB starting at bit#6

I8014=$278B3C  ; Entry 8 Unfiltered parallel pos of location Y:$78B3C
I8015=$011006  ; Width and Bias, total of 17-bits LSB starting at bit#6
```

Position (Ixx03) and Velocity (Ixx04) Pointers

```
I103=$3502     ; Motor 1 Position feedback address, ECT processed data
I104=$3502     ; Motor 1 Velocity feedback address, ECT processed data
I203=$3504     ; Motor 2 Position feedback address, ECT processed data
I204=$3504     ; Motor 2 Velocity feedback address, ECT processed data
I303=$3506     ; Motor 3 Position feedback address, ECT processed data
I304=$3506     ; Motor 3 Velocity feedback address, ECT processed data
I403=$3508     ; Motor 4 Position feedback address, ECT processed data
I404=$3508     ; Motor 4 Velocity feedback address, ECT processed data
I503=$350A     ; Motor 5 Position feedback address, ECT processed data
I504=$350A     ; Motor 5 Velocity feedback address, ECT processed data
I603=$350C     ; Motor 6 Position feedback address, ECT processed data
I604=$350C     ; Motor 6 Velocity feedback address, ECT processed data
I703=$350E     ; Motor 7 Position feedback address, ECT processed data
I704=$350E     ; Motor 7 Velocity feedback address, ECT processed data
I803=$3510     ; Motor 8 Position feedback address, ECT processed data
I804=$3510     ; Motor 8 Velocity feedback address, ECT processed data
```

Motor Activation

```
I100,8,100=1   ; Motors 1-8 Activated
```

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window.

Yaskawa Incremental Encoder Alarm Codes

Yaskawa Incremental encoder Alarm Registers			
Channel 1	Y:$78B22,8,8	Channel 5	Y:$78B32,8,8
Channel 2	Y:$78B26,8,8	Channel 6	Y:$78B36,8,8
Channel 3	Y:$78B2A,8,8	Channel 7	Y:$78B3A,8,8
Channel 4	Y:$78B2E,8,8	Channel 8	Y:$78B3E,8,8

Bit#	**Error Name**	**Type**	**Alarm Type**	**Clear Action**	**Notes**
8	Fixed at "1"	-	-	-	
9	Encoder Error	Alarm	Session Flag	Power cycle	Encoder Error
10	Fixed at "0"	-	-	-	
11	Position Error	Alarm	Session Flag	Power cycle	Possible error in position or Hall sensor
12	Fixed at "0"	-	-	-	
13	Fixed at "0"	-	-	-	
14	Origin not passed flag	Warning	-	-	The origin has not been passed in this session yet
15	Fixed at "0"				Set at zero

Homing with Yaskawa Incremental Encoders

Hardware capture is not available with serial data encoders, software capture (Ixx97=1) is required. Setting Ixx97 to 1 tells Turbo PMAC to use the register whose address is specified by Ixx03 for the trigger position. The disadvantage is that the software capture can have up to 1 background cycle delay (typically 2-3 msec), which limits the accuracy of the capture. To alleviate homing inaccuracies with serial encoders, it is recommended to perform home search moves at low speeds.

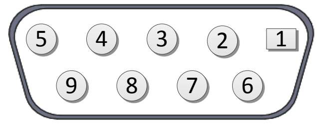
Homing to a flag (i.e. Home, Overtravel Limit, and User) is done using the traditional capture parameters I7mn2, and I7mn3. Remember to (temporarily) disable the end of travel limit use (bit#17 of Ixx24) when homing to one of the hardware limit flags, and re-enabling it when homing is finished. Example:
Homing channel 1 to the negative limit (high true)

```
I124=I124|$20001       ; Flag Mode, Disable hardware over travel limits
I197=1                 ; channel 1 position capture, software
I7012=2                ; Channel 1 capture control, capture on flag high
I7012=2                ; Channel 1 capture flag select, minus or negative end limit
```

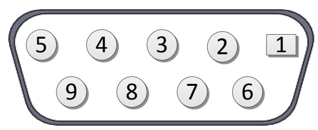
Homing to the index pulse, normally performed after referencing to a hardware flag, is an internal function of the Yaskawa encoder. Bit 14 of the alarm code indicates whether the index has been detected since last power-up. The motor should be jogged until bit 14 is low, the encoder will then place the "incremental compensation" value in the lower 11 bits of the second data word. Subtracting the "incremental compensation" from the "incremental position" results into the true position of the index. Motor 1 index detection example plc:

```
#define FirstWord          M7025
#define SecondWord         M7026
#define OriginNotPassed    M7027

FirstWord->Y:$78B20,0,24
SecondWord->Y:$78B21,0,24
OriginNotPassed->Y:$78B22,14

#define Mtr1ActPos      M162  ; Suggested M-Variable Definition, Motor 1 Actual Position
Mtr1ActPos->D:$00008B         ; #1 Actual position (1/[Ixx08*32] cts)

open plc 1 clear
if (OriginNotPassed = 1)
   cmd "#1j+"                 ; Jog in positive direction looking for index
   while (OriginNotPassed = 1); wait until index is detected
   endwhile
   cmd "#1k"                  ; Kill Motor
endif
while (SecondWord & $8FF = 0) ; Incremental Compensation takes up to 2 msec to execute
endwhile
Mtr1ActPos = int (((FirstWord & $8FFFC0) / $40)-((SecondWord & $8FF) * $40))* I108 * 32
disable plc 1
close
```

X9-X10: Analog Inputs/Outputs

X9-X10: D-Sub DE-9F **Mating: D-Sub DE-9M**			
Pin #	**Symbol**	**Function**	**Notes**
1	AGND	Ground	Analog Ground
2	ADC+	Input	16-bit Analog Input, channel 5/6+
3	DAC+	Output	12-bit filtered PWM analog output, channel 5/6+
4	BR-NC	Output	Brake 5-6 / Relay Normally Closed
5	AMPFLT	Input	Amplifier fault Input 5/6
6	ADC-	Input	16-bit Analog Input, channel 5/6-
7	DAC-	Output	12-bit filtered PWM analog output, channel 5/6-
8	BRCOM	Common	Brake 5-6 / Relay Common
9	BR-NO	Output	Brake 5-6 / Relay Normally Open

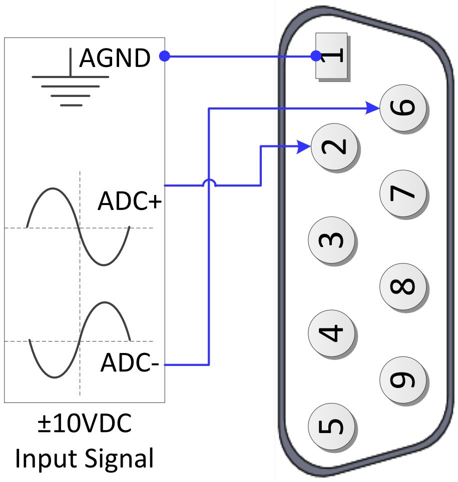
X11-X12: Analog Inputs/Outputs

X11-X12: D-Sub DE-9F **Mating: D-Sub DE-9M**			
Pin #	**Symbol**	**Function**	**Notes**
1	AGND	Ground	Analog Ground
2	ADC+	Input	16-bit Analog Input, channel 7/8+
3	DAC+	Output	12-bit filtered PWM analog output, channel 7/8+
4	BR-NC	Output	Brake 3-4 / Relay Normally Closed
5	AMPFLT	Input	Amplifier fault Input 7/8
6	ADC-	Input	16-bit Analog Input, channel 7/8-
7	DAC-	Output	12-bit filtered PWM analog output, channel 7/8-
8	BRCOM	Common	Brake 3-4/ Relay Common
9	BR-NO	Output	Brake 3-4 / Relay Normally Open

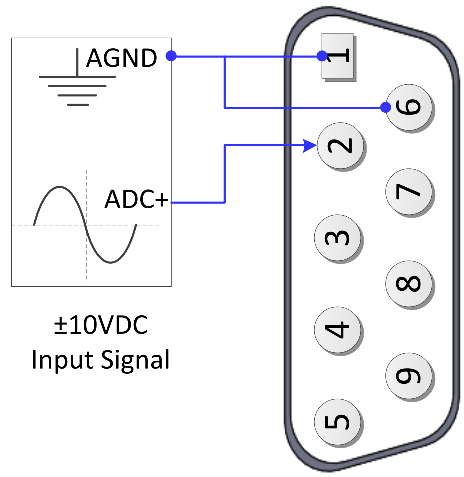
Setting Up The Analog (ADC) Inputs

For single-ended connection, tie the negative ADC pin to ground.

Differential Analog Input Signal



Single Ended Analog Input Signal



Note

- The converter device used for analog inputs on X9 through X12 is **ADS8321**.
- Full (16-bit) resolution is available for bipolar signals only. Half of the range of the full resolution is used for unipolar (0-5V or 0-10V) signals.

Analog Inputs Suggested M-Variables

```
// Analog Input, Connector X9:
M505->Y:$078105,8,16,S          ; ADC Input value (ADC5A)
// Analog Input, Connector X10:
M605->Y:$07810D,8,16,S          ; ADC Input value (ADC6A)
// Analog Input, Connector X11:
M705->Y:$078115,8,16,S          ; ADC Input value (ADC7A)
// Analog Input, Connector X12:
M805->Y:$07811D,8,16,S          ; ADC Input value (ADC8A)

//ADC Strobe Word Setup:
I7106=$1FFFFF                   ; Servo IC1 ADC Strobe Word
```

Testing the Analog Inputs

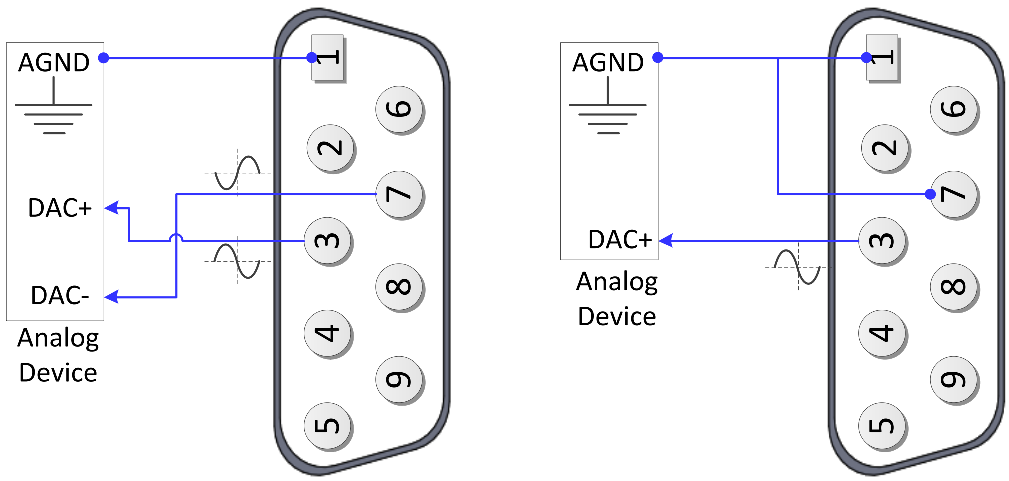
The software counts range (reading) is $-2^{16}/2$ to $2^{16}/2$, so that:

<table>
<tr><th></th><th></th><th>Single-Ended Signal [VDC]</th><th>Differential Signal [VDC]</th><th>Software Counts</th></tr>
<tr><td></td><td rowspan="3">Bipolar</td><td>-10</td><td>-5</td><td>-32768</td></tr>
<tr><td rowspan="2">Unipolar</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>10</td><td>5</td><td>+32768</td></tr>
</table>

Setting Up The Analog (DAC) Outputs

For single-ended connection, tie the negative DAC pin to ground.

Differential DAC Output Signal **Single Ended DAC Output Signal**



The analog outputs on X9 through X12 are (12-bit) filtered PWM signals. For a minimum ripple and good quality signal, a PWM frequency in the range of 30-36 KHz and a PWM deadtime of zero are recommended.

A fully populated Geo Brick Drive can have one of three clock generators (gates); Servo IC0, Servo IC1, and MACRO IC0. Variable I19 specifies which gate is used as the master gate (providing phase and servo clocks). Servo IC0 is the Master by default (i.e. I19=7007). The analog outputs on X9 through X12 come from Servo IC1. The relationship between the PWM clock of Servo IC1 and the master gate (normally Servo IC0) should always be respected, such as:

$$f_{\text{PWM (Clock Recipients)}} = \frac{n}{2} f_{\text{PHASE (Clock Generator)}} \qquad \text{Where n is an integer}$$

Examples:

At default clock settings and master gate Servo IC0 (I19=7007), the recommended Servo IC1 clock settings for a good quality analog output:

Servo IC0	Generator Clocks [KHz]	
I7000=6527	PWM	4.5
I7001=0	PHASE	9
I7002=3	SERVO	2.25
I10=3713991		

Servo IC1	Recipient Clocks [KHz]	
I7100=816	PWM	36
I7101=7	PHASE	9
I7102=3	SERVO	2.25
I7104=0	$PWM_{Deadtime}$	0

Note that n=8 in this case

With enhanced clock settings and master gate Servo IC0 (I19=7007), the recommended Servo IC1 clock settings for a good quality analog output:

Servo IC0	Generator Clocks [KHz]	
I7000=3275	PWM	9
I7001=0	PHASE	18
I7002=3	SERVO	4.5
I10=1863964		

Servo IC1	Recipient Clocks [KHz]	
I7100=816	PWM	36
I7101=3	PHASE	18
I7102=3	SERVO	4.5
I7104=0	$PWM_{Deadtime}$	0

Note that n=4 in this case

Note

These Servo IC1 clock settings are optimized for a good quality analog output signal. If any one of axes 5-8 is used for direct PWM control then the analog output signal quality should be compromised with a much lower PWM frequency, or not used at all.

For Help with clock settings, use the Delta Tau Calculator: **DT Calculator Forum Link**

Analog Outputs Suggested M-Variables:

```
// De-activate Motors 5-8 to write directly to the analog outputs
I500,4,100=0                ; De-activate channels 5-8
I569,4,100=816              ; Set Output Limit --User Input

// Analog Outputs:
M502->Y:$078102,8,16,S      ; Analog DAC Output (DAC5), Connector X9
M602->Y:$07810A,8,16,S      ; Analog DAC Output (DAC6), Connector X10
M702->Y:$078112,8,16,S      ; Analog DAC Output (DAC7), Connector X11
M802->Y:$07811A,8,16,S      ; Analog DAC Output (DAC8), Connector X12
```

Testing the Analog Outputs

With the setting of I7100=816 (per the above example), writing directly to the assigned M-variable (i.e. Mxx02) should produce the following voltage output:

Mxx02	Single Ended [VDC]	Differential [VDC]
-816	-10	-20
-408	-5	-10
0	0	0
408	+5	+10
816	+10	+20

The output voltage is measured between AGND and DAC+ for single-ended operation and between DAC- and DAC+ for differential operation.

Note

Writing values greater than I7100 (i.e. 816) in Mx02 will saturate the output to 10, or 20 volts in single-ended or differential mode respectively.

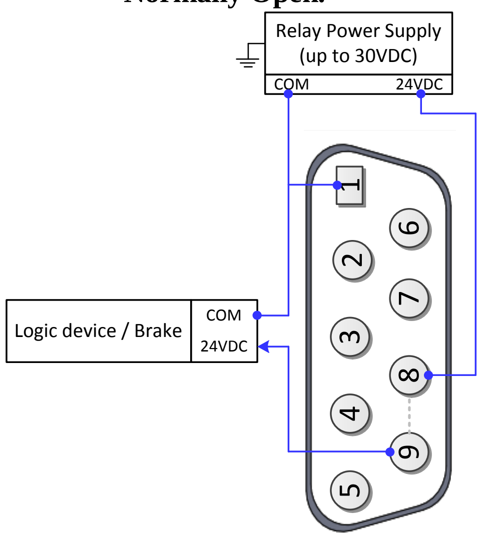
Setting Up The General Purpose Relay, Brake

This option provides either a general purpose relay (which can be toggled in software) OR a dedicated brake relay tied to its' respective channel amplifier enable line. The brake relay is commonly used in synchronizing (in hardware) external events such as automatically releasing a motor brake upon enabling it (i.e. vertical axis). In this mode, the general purpose relay has no use, and the related registers (suggested M-variables) are meaningless.

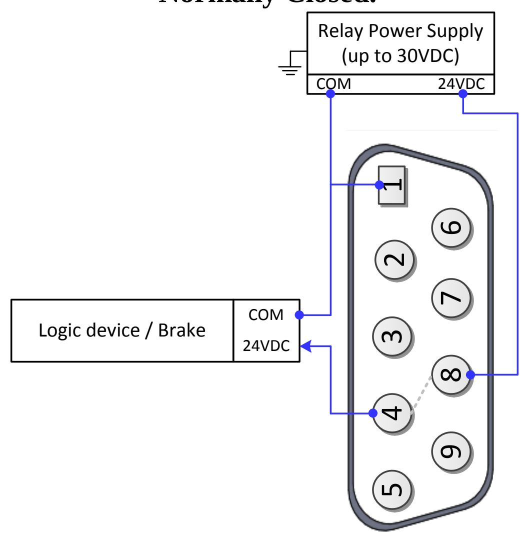
Caution

This option utilizes the **Omron G6S-2F** relay, which is rated to up to 220VAC. However, it is advised to use an external relay for AC operations, and limit the usage for this connection to up to 30VDC at 2 amperes.

General Purpose / Brake, Normally Open.



General Purpose / Brake, Normally Closed.



The following table summarizes the mode of operation:

Operation	Mode	Connection between pins #8 and #9	Connection between pins #8 and #4
Brake	Amp. disabled (killed)	Open	Closed
	Amp. enabled	Closed	Open
GP Relay	M-variable = 0	Open	Closed
	M-variable = 1	Closed	Open

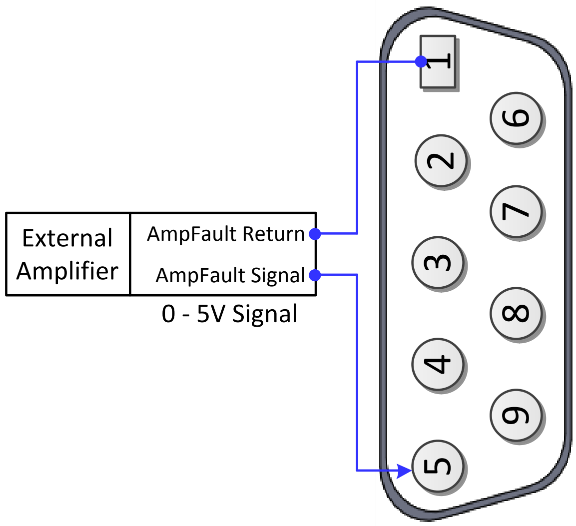
Note

- The optional brake relays on X11, X12 are tied to amplifier enable signals axes 3 and 4 respectively.
- The optional brake relays on X9, X10 are tied to amplifier enable signals axes 5 and 6 respectively.

General Purpose Relay Suggested M-Variables

```
// General purpose relay Outputs:
M5014->Y:$078800,8,1          ; General purpose relay output, X9
M6014->Y:$078801,8,1          ; General purpose relay output, X10
M7014->Y:$78803,8,1           ; General purpose relay output, X11
M8014->Y:$78804,8,1           ; General purpose relay output, X12
```

Setting Up The External Amplifier Fault Input



Note

The external amplifier fault inputs on X9 through X12 are (internally) tied to amplifier fault signals channels 5 through 8 respectively.

```
// External Amplifier Fault Input, Connector X9:
M523->X:$078100,15,1          ; Amp. Fault Output (CH5, can be used as general purpose Input)
// External Amplifier Fault Input, Connector X10:
M623->X:$078108,15,1          ; Amp. Fault Output (CH6, can be used as general purpose Input)
// External Amplifier Fault Input, Connector X11:
M723->X:$078110,15,1          ; Amp. Fault Output (Ch7, can be used as general purpose Input)
// External Amplifier Fault Input, Connector X12:
M823->X:$078118,15,1          ; Amp. Fault Output (Ch8, can be used as general purpose Input)
```

This option is most commonly used when an external amplifier is controlled by the Geo Brick Drive, and the need of an amplifier fault input is required to run the operation safely (i.e. kill in the occurrence of an amplifier fault).

Note

If these pins are not used for external amplifier fault inputs, they can be treated and used as general purpose +5V TLL level inputs.

X13: USB 2.0 Connection

This connector is used to establish USB (A-B type cable) communication between the host PC and the Geo Brick Drive. This type of USB cable can be purchased at any local electronics or computer store. It may be ordered from Delta Tau as well.

Pin #	Symbol	Function
1	VCC	N.C.
2	D-	Data-
3	D+	Data+
4	Gnd	GND
5	Shell	Shield
6	Shell	Shield

Caution

The electrical ground plane of the host PC connected through USB must be at the same level as the Geo Brick drive. Ground loops may result in ESD shocks causing the damage of the communication processor on the Geo Brick Drive.

Note

Use a shielded USB (category 6 or 7) cable. In noise sensitive environment, install ferrite cores at both Geo Brick and PC side.

If the electrical ground planes of the host PC and the Geo Brick Drive are not at the same level (e.g. laptop on battery) then the use of an industrial USB hub is highly advised. This **USB Hub** from B&B Electronics or similar component can be used.

X14: RJ45, Ethernet Connection

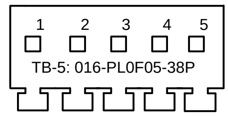
This connector is used to establish Ethernet communication between the PC and the Geo Brick Drive. A crossover cable is required if you are going directly to the Geo Brick from the PC Ethernet card. Otherwise, through a hub, a straight Ethernet cable is acceptable.

Delta Tau strongly recommends the use of RJ45 CAT5e or better shielded cable. Newer network cards have the Auto-MDIX feature that eliminates the need for crossover cabling by performing an internal crossover when a straight cable is detected during the auto-negotiation process. For older network cards, one end of the link must perform media dependent interface (MDI) crossover (MDIX), so that the transmitter on one end of the data link is connected to the receiver on the other end of the data link (a crossover/patch cable is typically used). If an RJ45 hub is used, then a regular straight cable must be implemented. Maximum length for Ethernet cable should not exceed 100m (330ft).

X15: Watchdog & ABORT (TB2)

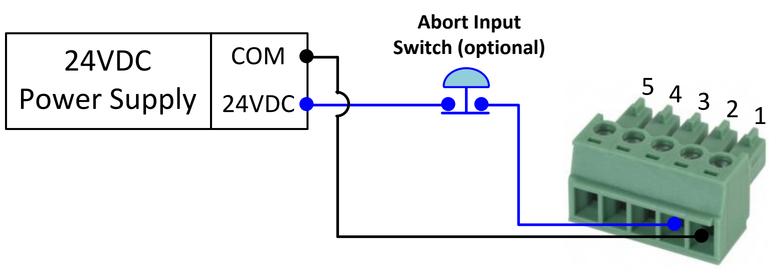
X15 has two essential functions:

- A 24VDC Abort Input (mandatory for normal operation) which can be used in various applications to halt motion when necessary (i.e. opening machine door, replacing tool).
- A watchdog relay output allowing the user to bring the machine to a stop in a safe manner in the occurrence of a watchdog.

X15: Phoenix 5-pin TB Female Mating: Phoenix 5-pin TB Male			
Pin #	**Symbol**	**Function**	**Notes**
1	ABORT-	Input	ABORT Return
2	ABORT+	Input	ABORT Input 24VDC
3	WD N.O.	Output	Watchdog (normally open contact)
4	WD N.C.	Output	Watchdog (normally closed contact)
5	WD COM	Common	Watchdog common

Wiring The Abort Input

If an Abort toggle button is used, it must be a normally closed switch.



The hardware Abort input functionality differs slightly from the software global Abort (CTRL-A) command. The main differences are highlighted in the following table:

Motor(s) Status Before Abort Action	**Software Abort (e.g. ^A)**	**Hardware Abort (Removing 24VDC)**
Killed (Open-Loop mode)	Closes the position-loop on all active (Ixx0=1) motors	No Action is taken. Motors remain killed
Amplifier Enabled (i.e. #1o0, Open-Loop mode)	Closes the position-loop on all active (Ixx0=1) motors	Closes the position-loop on all 'amplifier enabled' motors only. Killed motors remain killed.
Servo-ing – in position (Closed-Loop mode)	Motor(s) remain in closed-loop at velocity zero	Motor(s) remain in closed-loop at velocity zero
Servo-ing – Jogging (Closed-Loop mode)	Motor(s) decelerate to zero velocity at Ixx15 rate	Motor(s) decelerate to zero velocity at Ixx15 rate
Servo-ing – Running Program(s) (Closed-Loop mode)	Aborts motion program(s) and decelerate to zero velocity at Ixx15 rate	Aborts motion program(s) and decelerate to zero velocity at Ixx15 rate

Note

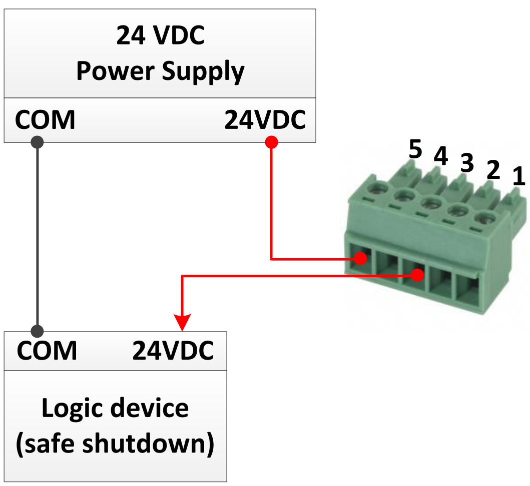
Motors killed at the time of the “hardware” abort remain killed.

Note

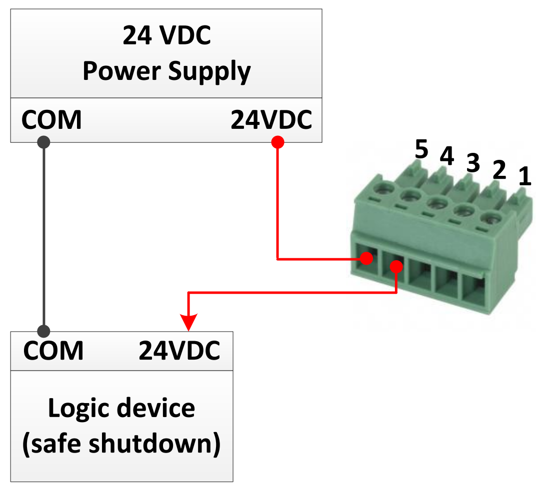
In the Geo Brick Drive, there are no software configurable parameters to enable or disable the hardware Abort Input functionality.

Wiring The Watchdog Output

Watchdog Output, Normally Open



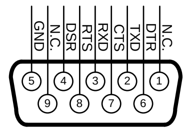
Watchdog Output, Normally Closed



Operation	Mode	Connection between pins #5 and #3	Connection between pins #5 and #4
Watchdog	Not triggered (normal operation)	Open	Closed
	Triggered (Faulty operation)	Closed	Open

RS232: Serial Communication Port

An optional serial RS-232 communication port is available on the Geo Brick Drives. This port can be used as a primary communication mean or employed as a secondary port that allows simultaneous communication.

RS-232: D-Sub DE-9F **Mating: D-Sub DE-9M**			 	
Pin#	**Symbol**	**Function**	**Description**	**Notes**
1	N.C.		NC	
2	TXD	Output	Receive data	Host transmit Data
3	RXD	Input	Send data	Host receive Data
4	DSR	Bi-directional	Data set ready	Tied to “DTR”
5	GND	Common	Common GND	
6	DTR	Bi-directional	Data term ready	Tied to “DSR”
7	CTS	Input	Clear to send	Host ready bit
8	RTS	Output	Req. to send	PMAC ready bit
9	N.C		NC	

The baud rate for the RS-232 serial port is set by variable I54. At power-up reset, The Geo Brick Drive sets the active baud based on the setting of I54 and the CPU speed I52. Note that the baud rate frequency is divided down from the CPU’s operational frequency. The factory default baud rate is 38400. This baud rate will be selected automatically on re-initialization of the Geo Brick Drive, either in hardware using the re-initialization (RESET SW) button or in software using the **`$$$***`** command.

To change the baud rate setting on the Geo Brick Drive, set I54 to the corresponding value of desired frequency. Restart the software (Pewin32Pro2), and adjust to the correct baud rate in the communication setup window. Then issue a **SAVE** and a reset (**$$$**), or recycle power on the Geo Brick Drive. For odd baud rate settings, refer to the Turbo Software Reference Manual.

I54	Baud Rate	I54	Baud Rate
8	9600	12	38,400
9	14,400	13	57,600
10	19,200	14	76,800
11	28,800	15	115,200

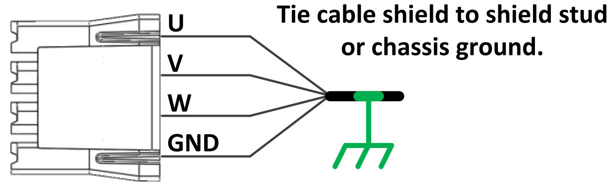
Note

I54=12 (38400 baud) is the factory default setting

A1 - A8: Motor Wiring

Low (5/10A) – Medium (8/16A) power Axes:

A1 - A8: Molex 4-pin Female
Mating: Molex 4-pin Male



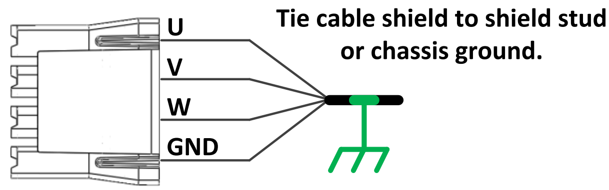
Pin #	Symbol	Function	Description	Notes
1	GND	Common		
2	W	Output	Axis 1-8 Phase 3	
3	V	Output	Axis 1-8 Phase 2	
4	U	Output	Axis 1-8 Phase 1	

Molex Mating p/n: 0444412004
Molex Pins p/n: 0433750001
Molex Crimper tool p/n: 63811-0400

Delta Tau Connector p/n: 014-000F04-HSG (for internal use)
Delta Tau Pins p/n: 014-043375-001 (for internal use)

High (15/30A) power Axes:

A5 - A6: Molex 4-pin Female
Mating: Molex 4-pin Male



Pin #	Symbol	Function	Description	Notes
1	GND	Common		
2	W	Output	Axis 5-6 Phase 3	
3	V	Output	Axis 5-6 Phase 2	
4	U	Output	Axis 5-6 Phase 1	

Molex Mating Connector p/n: 0428160412
Molex Pins p/n: 0428150031
Molex Crimper Tool p/n: 63811-1500

Delta Tau Mating Connector p/n: 014-H00F04-049 (for internal use)
Delta Tau Pins p/n: 014-042815-031 (for internal use)

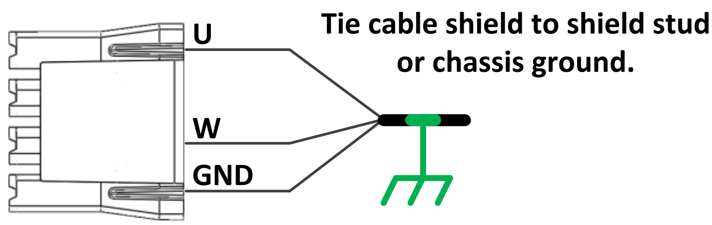
Note

Low and medium power axes use smaller connectors than the high power axes.

Note

The Geo Brick Drive endorses U, V, and W nomenclature for phases 1 through 3 respectively. Some motor manufacturers will call them A, B, and C. Others may call them L1, L2, and L3.

For wiring DC brush motors, use phases U and W, and leave V floating:



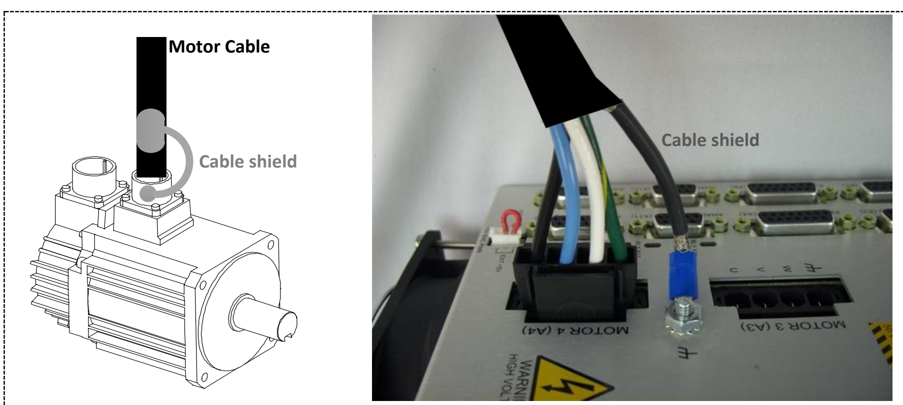
DC brush motor wiring

Motor Cable, Noise Elimination

The Geo Brick Drives' voltage output has a fundamental frequency and amplitude that corresponds to motor speed, torque, and number of poles. As a Direct Digital PWM Drive, the Geo Brick produces higher frequency voltage components corresponding to the rise, fall and repetition rate of the fast switching PWM signals. Subsequently, it could naturally couple current noise to nearby conductors. This electrical coupling can be problematic, especially in noise-sensitive applications such as using high-resolution sinusoidal encoders, or high rate of communication which could suffer from Electro-Magnetic Interference EMI. Proper grounding, shielding, and filtering can alleviate most noise issues. Some applications may require additional measures such as PWM edge filters. The following; are general guidelines for proper motor cabling:

- Use a motor cable with **high quality shield**. A combination braid-and-foil is best.

- **The motor drain wires and cable shield should be tied together, and attached at both ends of the motor and Geo Brick Drive chassis**. At the motor end, make a 360 degree connection between the shield and motor frame. If the motor has a metal shell connector, then you can tie the shield directly to the metal shell of the mating connector. The connection between the cable shield and the motor frame should be as short as possible). At the Geo Brick Drive end, make a 360 degree connection between the shield and the provided studs or grounded chassis (protection earth) at the M4 mounting screws.

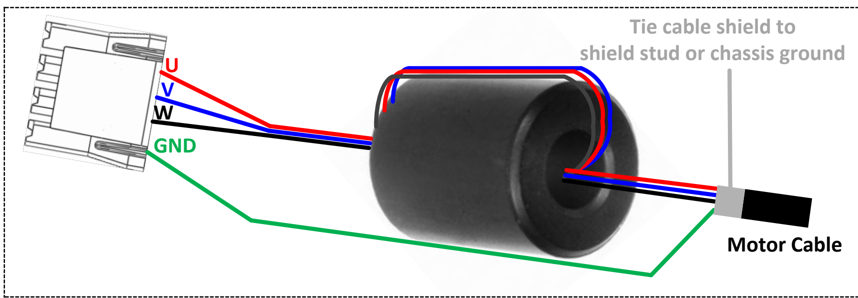


Motor Side **Geo Brick Side**

- The motor cable should have a **separate conductor (drain wire) tying the motor frame to the Geo Brick drive**.

- **Keep the motor cable as short as possible** to maintain lower capacitance (desirable). A capacitance of up to 50 PicoFarads per foot (0.3048 m), and runs of up to 200 feet (60 m) are acceptable with 240VAC. Exceeding these lengths requires the installation of a Snubber at the motor end or an in-series inductor at the Geo Brick Drive end.

- If the grounding/shielding techniques are insufficient, you may **install chokes in the motor phases at the Geo Brick Drive end** such as wrapping individual motor leads several times through a ferrite core ring. DigiKey, Micro-Metals (T400-26D), Fair Rite (2643540002), or equivalent ferrite cores are recommended. This adds high-frequency impedance to the outgoing motor cable thereby making it harder for high-frequency noise to leave the control area.



Note

Ferrite cores are also commonly used with lower inductance motors to enhance compatibility with the Geo Brick Drive, which is specified to a minimum of 2 mH.

- **Do not use a motor wire gauge less than 14 AWG for 5/10A or 8/16A axes, and 10 AWG for 15/30A axes** unless otherwise specified by the motor manufacturer. Refer to Motor manufacturer and local code recommendations.

- Avoid running sensitive signal cables (i.e. encoders, small signal transducers) in the same cable bundle as the motor cable(s).

- Install dv/dt filter, Trans-coil V1K series (Optional).

Motor Selection

The Geo Brick Drive interfaces with a wide variety of motors. It supports virtually any kind of three-phase AC/DC rotary, linear brushless, or induction motors. Using two out of the three phases, it is also possible to drive permanent magnet DC brush motors.

Motor Inductance

Digital direct PWM control requires a significant amount of motor inductance to drive the on-off voltage signals resulting smooth current flow with minimal ripple. Typically, servomotors' phase inductance ranges from 1 to 15mH. The lower the inductance, the higher is the suitable PWM frequency.
Low inductance motors (less than 1 mH) can see large ripple currents causing excessive energy waste and overheating. Additional in-series inductance is recommended in these cases.
High inductance motors (greater than 15 mH) are slower to react and generally not considered high performance servo motors.

Motor Resistance

Motor resistance is not typically a determining factor in the drive/system performance but rather comes into play when extracting a desired torque or horsepower out of the motor is a requirement.

Motor Inertia

Motor inertia is an important parameter in motor sizing. Considering the reflected load inertia back to the motor in this process is important. In general, the higher the motor inertia, the more stable the system will inherently be. A high ratio of load to motor inertia shrinks the operating bandwidth (gain limited) of the system, especially in applications using belt or rubber based couplings. The ratio of load to motor inertia is typically around 3:1. Mechanical gearing is often used to reduce reflected inertial load going back to the shaft of the motor.

Motor Speed

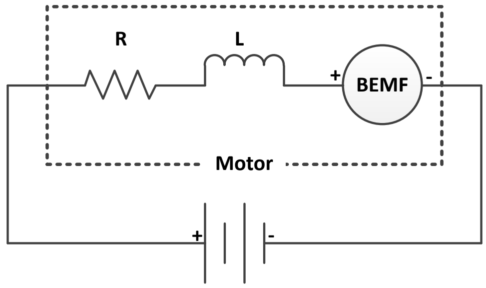
In some applications, it is realistically impossible to achieve the motors' specified maximum velocity. Fundamentally, providing sufficient voltage and proper current-loop tuning should allow attaining motor maximum speeds. Consider feedback devices being a limitation in some cases, as well as the load attached to the motor. In general, the maximum speed can be determined dividing the line-to-line input voltage by the back EMF constant Kb of the motor. Input voltage headroom of about 20% is recommended for good servo control at maximum speed.

Motor Torque

Torque requirements in an application can be viewed as both instantaneous and average
Typically, the instantaneous or peak torque is the sum of machining, and frictional forces required to accelerate the inertial load. The energy required to accelerate a load follows the equation T=JA where T is the torque, J is the inertia, and A is the acceleration. The required instantaneous torque is then divided by the motor torque constant (Kt) to determine the necessary peak current of the Geo Brick Drive. Headroom of about 10% is always desirable to account for miscellaneous losses (aging, wear and tear, calculation roundups).
The continuous torque rating of the motor is bound by thermal limitation. If the motor applies more torque than the specified threshold, it will overheat. Typically, the continuous torque ceiling is the RMS current rating of the motor, also known as torque output per ampere of input current.

Required Bus Voltage for Speed And Torque

For a required motor Speed, and continuous Torque, the minimum DC Bus Voltage (V_{DC}) can be estimated by looking at the equivalent single phase circuit:



The vector sum of back EMF, voltage across resistor and inductor should be less than $V_{DC}/\sqrt{6}$.

For a Rotary Motor:

$$\sqrt{V_L^{\ 2} + (V_R + V_{BEMF})^2} = \sqrt{\left(\frac{R_{RPM}}{60} \cdot N_p \cdot 2 \cdot \pi \cdot L_p \cdot \frac{T_M}{K_t}\right)^2 + \left(\frac{T_M}{K_t} R_p + \frac{R_{RPM}}{60} \cdot \frac{K_t}{3} \cdot 2 \cdot \pi\right)^2} \le M_{derate} \frac{V_{DC}}{\sqrt{6}}$$

Where:

V_L	: Voltage Across equivalent inductor	L_P	: Phase Inductance [H]
V_R	: Voltage Across equivalent resistor	R_P	: Phase Resistance [Ω]
V_{BEMF}	: Back electromotive force voltage	T_M	: Required Continuous Torque [N.M]
R_{RPM}	: Required Motor Speed [rpm]	K_T	: Motor Torque Constant RMS [N.M/A]
N_P	: Number of pole pairs	M_{derate}	: De-rate parameter (typically 0.8)

For a Linear Motor:

$$\sqrt{V_L^{\ 2} + (V_R + V_{BEMF})^2} = \sqrt{\left(\frac{V_{motor}}{D_{pitch}} \cdot L_p \cdot \frac{F_M}{K_t}\right)^2 + \left(\frac{F_M}{K_t} R_p + \frac{V_{motor}}{D_{pitch}} \cdot \frac{K_t}{3}\right)^2} \le M_{derate} \frac{V_{DC}}{\sqrt{6}}$$

Where:

V_L	: Voltage across equivalent inductor	L_P	: Phase Inductance [H]
V_R	: Voltage across equivalent resistor	R_P	: Phase Resistance [Ω]
V_{BEMF}	: Back electromotive Force voltage	F_M	: Required Motor Force RMS [N]
V_{motor}	: Required Motor Speed [m/s]	K_t	: Motor Force Constant RMS [N/A]
M_{derate}	: De-rate parameter (typically 0.8)	D_{Pitch}	: Magnetic Pitch [m]

Example:

An application requires running a motor at 500 RPM with a continuous torque of 30 N.M. The motor specs are as follow:

$L_p = 10\text{mH}$, $R_p = 2\text{Ohm}$, $N_p = 16$, $K_t = 2.187\text{Nm/Amps}$

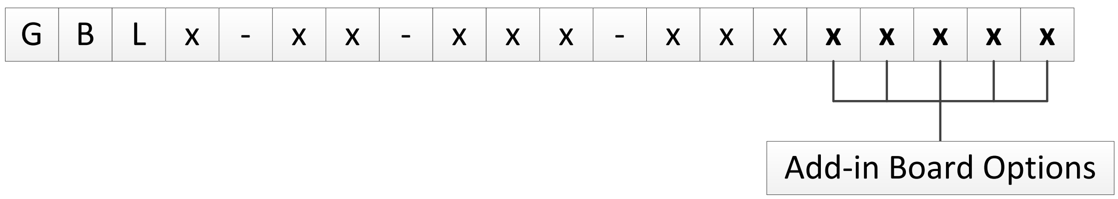
Using the equation above, a minimum bus of 233 VDC (~165VAC) is necessary to achieve the speed and torque requirements.

+5V ENC PWR (Alternate Encoder Power)

Generally, feedback devices are powered up through the X1-X8 connectors on the Geo Brick Drive using the internal +5VDC power supply. In some cases, feedback devices consume power excessively and risk of surpassing the internal power supply limitation.
This connector provides an alternate mean to power-up the feedback devices (+5V only) if the budget exceeds the specified thresholds.

Note

Encoders requiring other than +5VDC power must be supplied externally, and NOT through the X1-X8 connectors NOR through this +5VDC connector.



If the Geo Brick Drive is equipped with the add-in board, meaning any of the highlighted part number digits is a non-zero, then the total +5V encoder power available at X1-X8 is about 1 ampere.

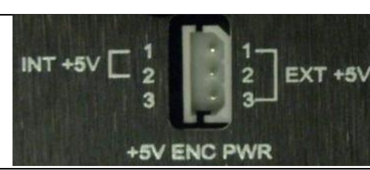
If the Geo Brick Drive is not equipped with the add-in board, meaning all the highlighted part number digits are zeros, then the total +5V encoder power available at X1-X8 is about 1.5 amperes.

Geo Brick Drive	Total Encoder Power Available [amps]	Power Per Encoder (4 Encoders) [mA]	Power Per Encoder (8 Encoders) [mA]
Without add-in board	1.5	375	188
with add-in board	1	250	125

Caution

The maximum current draw out of a single encoder channel must not exceed 750 mA.

Pin#	Symbol	Description	Note
1	5VEXT	Input	5V from external power supply
2	5VINT	Output	Tie to pin#1 to use internal power supply
3	GND	Common	

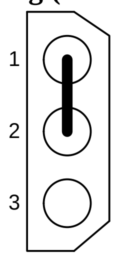
Mating Connector: Crimping tool:	Adam-Tech part number 25CH-E-03 Pins part number 25CTE-R Molex EDP#: 11-01-0208	

Caution

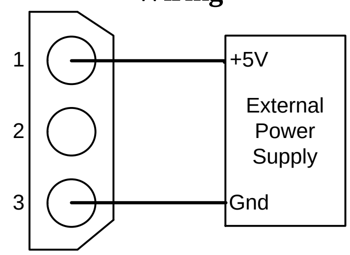
Only two of the three available pins should be used at one time. Do not daisy-chain the internal 5V power supply with an external one.

By default, pins 1-2 are tied together to use the internal power supply. To wire an external power supply, remove the jumper tying pins 1-2 and connect the external +5V to pin #1, and ground/common to pin#3:

Internal Power Supply Wiring (Default)



External Power Supply Wiring



Note

A jumper tying pins 1 and 2 is the default configuration. This is the configuration with which the Geo Brick Drive is shipped to a customer.

Note

The controller (PMAC) 5V logic is independent of this scheme, so if no encoder power is provided the PMAC will remain powered-up (provided the standard 24 volts is brought in).

Functionality, Safety Measures

There are a couple of safety and functionality measures to take into account when an external encoder power supply is utilized:

- Power sequence: encoders versus controller/drive
  It is highly recommended to power up the encoders before applying power to the Geo Brick Drive

- Encoder Power Loss (i.e. power supply failure, loose wire/connector)

The Geo Brick Drive, with certain feedback devices, can be setup to read absolute position or perform phasing on power-up (either automatic firmware functions, or user PLCs). If the encoder power is not available, these functions will not be performed properly. Moreover, trying to close the loop on a motor without encoder feedback can be dangerous.

Caution

Make sure that the encoders are powered-up before executing any motor/motion commands.

Losing encoder power can lead to dangerous runaway conditions, setting the fatal following error limit and I2T protection in PMAC is highly advised.

Caution

Make sure that the fatal following error limit and I2T protection are configured properly in PMAC.

With Commutated motors (i.e. DC brushless), a loss of encoder generally breaks the commutation cycle causing a fatal following error or I2T fault either in PMAC or Amplifier side. However, with non-commutated motors (i.e. DC brush), losing encoder signal can more likely cause dangerous runway conditions.

Note

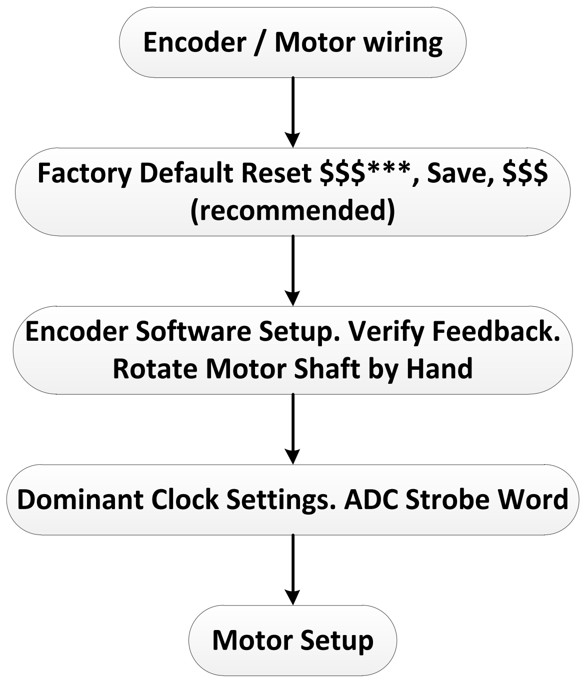
Setting up encoder loss detection for quadrature and sinusoidal encoders is highly recommended. Serial Encoders normally provide with a flag or timeout error bit that can be used for that function.

MOTOR SETUP

The Geo Brick Setup software can be used with digital quadrature type encoders for setting up motors. The Geo Brick Setup Software does not support special feedback devices (i.e. Sinusoidal, Serial, and Resolver) or MACRO connectivity. This section describes manual (step by step) instructions for setting up AC/DC brushless, AC induction, or brush motors.

Motor Setup Flow Chart

The following, is a diagram showing the basic steps to follow for successfully setting up a motor with the Geo Brick Drive:



Note

The Motor Setup section assumes that feedback device(s) have been setup properly, and that moving the motor/encoder shaft by hand shows correct data in the position window.

Dominant Clock Settings

The choice of clock settings usually relies on the system requirements, and type of application.

Minimum PWM Frequency

The minimum PWM frequency of a system is based on the time constant of the motor. In general, the lower the time constant, the higher the PWM frequency should be. The motor time constant is calculated dividing the motor inductance by the resistance (phase-phase). The minimum PWM Frequency is then determined using the following relationship:

$$\tau_{sec} = \frac{L_H}{R_\Omega} \quad ; \quad \tau_{sec} > \frac{20}{2 \times \Pi \times f_{PWM}}$$

$$=> \quad \boxed{f_{PWM}(\mathrm{Hz}) > \frac{20 \times R_\Omega}{2 \times \Pi \times L_H}}$$

Example: A motor with an inductance of 6.1 millihenries (mH), and a resistance of 11.50 Ohms (Ω phase-phase) yields a time constant of 0.53 milliseconds. Therefore, the minimum PWM Frequency is about ~6000Hz (6.0 KHz).

Note

Systems with very low time constants (needing higher PWM frequencies) may require the addition of chokes or in-line inductive loads to obtain a good current loop bandwidth.

Recommended clock Frequencies

The default clock settings in the Geo Brick Drive should work fine for the majority of applications, they are set as follows:

Phase Clock:	9.000 KHz
PWM Clock:	4.500 KHz
Servo Clock:	2.258 KHz

The need to change clock rates depends on specific requirements and motor/encoder hardware:

Phase Clock: The phase clock is directly related to the current loop calculation and current sensor reads. Typically, the phase clock is set to twice the PWM frequency. Setting it faster is meaningless and will not result in any performance enhancement.

PWM Clock: The PWM clock is directly related to the inductance and resistance of the motor. It can be calculated empirically as shown in the aforementioned equation.

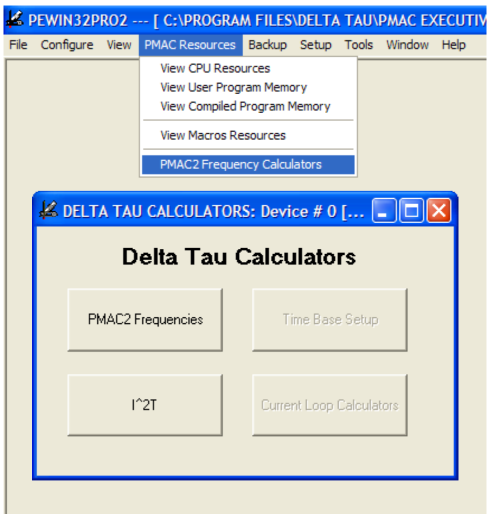
Servo Clock: The Servo clock is directly related to motor calculation and servo (encoder read, motor command write) update rate. Higher servo frequencies result, in general, in improved performance. The need for boosting the servo clock could come from several factors, such as high speed/precision applications, synchronizing to external events, position capture/compare at high rates, kinematics calculation. Hardware such as high resolution encoders (e.g. serial, sinusoidal), linear motors, and galvanometers are usually set up with higher servo rates for best results.

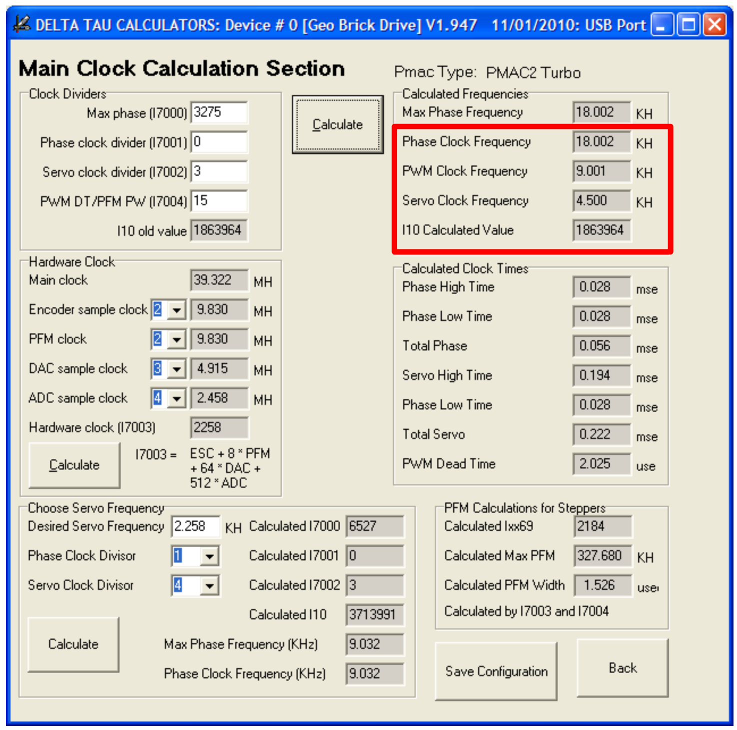
Hardware Clock: The hardware clock is directly related to sampling rates of encoders, digital /analog converters, and pulse frequency modulation PFM clock. With the Geo Brick Drive, the hardware clock setting (I7m03) is mostly used to set PFM clock frequencies. Also, for increasing the encoder sampling rate for high speed/resolution digital quadrature encoders.

The following, are recommended clock settings for enhanced performance. These settings should accommodate a wide variety of applications, from those performing simple positioning to those demanding more performance and faster calculation time:

Phase Clock: 18.000 KHz
PWM Clock: 9.0000 KHz
Servo Clock: 4.5000 KHz

The corresponding parameters for these clock settings can be found using the clock calculator in the Pewin32Pro2 under PMAC Resources >PMAC2 Frequency Calculators >PMAC2 Frequencies:





The equivalent script code for these settings:

```
I6800=3275      ; MACRO IC0 Max Phase/PWM Frequency Control
I6801=0         ; MACRO IC0 Phase Clock Frequency Control
I6802=3         ; MACRO IC0 Servo Clock Frequency Control

I7100=3275      ; Servo IC1 Max Phase/PWM Frequency Control
I7101=0         ; Servo IC1 Phase Clock Frequency Control
I7102=3         ; Servo IC1 Servo Clock Frequency Control

I7000=3275      ; Servo IC0 Max Phase/PWM Frequency Control
I7001=0         ; Servo IC0 Phase Clock Frequency Control
I7002=3         ; Servo IC0 Servo Clock Frequency Control

I10=1863964     ; Servo Interrupt Time
```

Note that writing to a non-existent Servo or Macro IC is usually neglected by PMAC but it is not a good practice for documentation purposes and future configuration(s). Use/download only parameters pertaining to the Servo and Macro ICs populating your unit:

Condition	Use/Download	Description
If I4900=$1 and I4902=$0	I7000s	Servo IC 0 present
If I4900=$3 and I4902=$0	I7100s and I7000s	Servo IC 0, 1 present
If I4900=$1 and I4902=$1	I6800s and I7000s	Servo IC 0 and Macro IC 0 present
If I4900=$3 and I4902=$1	I6800s, I7100s and I7000s	Servo IC 0, 1 and Macro IC 0 present

Note

Certain clock settings can be alternatively changed for specific functions (i.e. Filtered PWM output). This is explained in each pertaining section.

Clock Calculations

The following clock calculations are used in subsequent motor setup section(s) in certain downloadable scripts. They can also serve as a way to verify if the clock settings have been configured correctly:

```
I15=0                          ; Trigonometric calculation in degrees
#define MaxPhaseFreq   P8000   ; Max Phase Clock [KHz]
#define PWMClk         P8001   ; PWM Clock [KHz]
#define PhaseClk       P8002   ; Phase Clock [KHz]
#define ServoClk       P8003   ; Servo Clock [KHz]

MaxPhaseFreq=117964.8/(2*I7000+3)
PWMClk=117964.8/(4*I7000+6)
PhaseClk=MaxPhaseFreq/(I7001+1)
ServoClk=PhaseClk/(I7002+1)
```

ADC Strobe Word (I7m06)

In normal mode operation (see also enhanced mode section), the ADC Strobe word(s) on a Geo Brick Drive should be set to $3FFFFF.

```
I7106=$3FFFFF          ; Servo IC 1 ADC Strobe Word
I7006=$3FFFFF          ; Servo IC 0 ADC Strobe Word
```

Note

The ADC Strobe Word can be alternatively changed for specific functions (i.e. Analog Inputs, IGBT temperature, or bus readings). See enhanced mode section.

Note

Turbo PMAC firmware version 1.947 or later sets the ADC strobe word in the Geo Brick Drive to $3FFFFF automatically (by default).

AC/DC Brushless (Rotary/Linear) Motor Setup

Before you start

- At this point of the setup process it is assumed that the encoder has been wired and configured correctly in the Encoder Feedback section. And that moving the motor/encoder shaft by hand shows encoder counts in the position window.
- Parameters with comments ending with **-User Input** require the user to enter information pertaining to their system/hardware.
- Downloading and using the suggested M-variables is highly recommended.
- Description of the setup parameters can be found in the Turbo Software Reference Manual

Commutation Angle, Current Mask: Ixx72, Ixx84

```
I172,8,100=1365         ; Motors 1-8 Commutation phase angle (Geo Brick Drive specific)
I184,8,100=$FFF000      ; Motors 1-8 Current-Loop Feedback Mask Word (Geo Brick Drive specific)
```

PWM Scale Factor: Ixx66

If Motor Rated Voltage > Bus Voltage:

```
I166=1.10*I7000         ; Motor #1 PWM Scale Factor. Set to 10% above PWM Count.
I266=I166 I366=I166 I466=I166 I566=I166       ; Assuming same motor(s) as motor #1
I666=I166 I766=I166 I866=I166                 ; Assuming same motor(s) as motor #1
```

If Bus Voltage > Motor Rated Voltage:

Ixx66 acts as a voltage limiter. In order to obtain full voltage output it is set to about 10% over PWM count divided by DC Bus/Motor voltage ratio. For example:

```
#define DCBusInput     325     ; DC Bus Voltage [VDC] = 1.414* 230 VAC -User Input

#define Mtr1Voltage    156     ; Motor 1 Rated Voltage [VDC], 110 VAC Motor -User Input
#define Mtr2Voltage    156     ; Motor 2 Rated Voltage [VDC], 110 VAC Motor -User Input
#define Mtr3Voltage    156     ; Motor 3 Rated Voltage [VDC], 110 VAC Motor -User Input
#define Mtr4Voltage    156     ; Motor 4 Rated Voltage [VDC], 110 VAC Motor -User Input
#define Mtr5Voltage    156     ; Motor 5 Rated Voltage [VDC], 110 VAC Motor -User Input
#define Mtr6Voltage    156     ; Motor 6 Rated Voltage [VDC], 110 VAC Motor -User Input
#define Mtr7Voltage    156     ; Motor 7 Rated Voltage [VDC], 110 VAC Motor -User Input
#define Mtr8Voltage    156     ; Motor 8 Rated Voltage [VDC], 110 VAC Motor -User Input

I166=1.10*I7000*Mtr1Voltage/DCBusInput       ; Motor 1 PWM Scale Factor
I266=1.10*I7000*Mtr2Voltage/DCBusInput       ; Motor 2 PWM Scale Factor
I366=1.10*I7000*Mtr3Voltage/DCBusInput       ; Motor 3 PWM Scale Factor
I466=1.10*I7000*Mtr4Voltage/DCBusInput       ; Motor 4 PWM Scale Factor
I566=1.10*I7000*Mtr5Voltage/DCBusInput       ; Motor 5 PWM Scale Factor
I666=1.10*I7000*Mtr6Voltage/DCBusInput       ; Motor 6 PWM Scale Factor
I766=1.10*I7000*Mtr7Voltage/DCBusInput       ; Motor 7 PWM Scale Factor
I866=1.10*I7000*Mtr8Voltage/DCBusInput       ; Motor 8 PWM Scale Factor
```

Current Feedback Address: Ixx82

```
I182=$078006            ; Motor 1 Current Feedback Address
I282=$07800E            ; Motor 2 Current Feedback Address
I382=$078016            ; Motor 3 Current Feedback Address
I482=$07801E            ; Motor 4 Current Feedback Address
I582=$078106            ; Motor 5 Current Feedback Address
I682=$07810E            ; Motor 6 Current Feedback Address
I782=$078116            ; Motor 7 Current Feedback Address
I882=$07811E            ; Motor 8 Current Feedback Address
```

Commutation Position Address, Commutation Enable: Ixx83, Ixx01

Quadrature / Sinusoidal / HiperFace

For these types of feedback devices, it is recommended to use the quadrature data for commutation. And Ixx01 should be equal to 1, indicating commutation from an X-register:

```
I183=$078001   ; Motor 1 Commutation source address
I283=$078009   ; Motor 2 Commutation source address
I383=$078011   ; Motor 3 Commutation source address
I483=$078019   ; Motor 4 Commutation source address
I583=$078101   ; Motor 5 Commutation source address
I683=$078109   ; Motor 6 Commutation source address
I783=$078111   ; Motor 7 Commutation source address
I883=$078119   ; Motor 8 Commutation source address

I101,8,100=1   ; Motors 1-8 Commutation Enabled, from X-register
```

SSI / EnDat / BiSS

- **Technique 1**

PMAC expects the commutation data to be left most shifted. With technique 1, this is satisfied if the encoder data fulfills or exceeds 24 bits. But if the data length is less than 24 bits then it is recommended, for simplicity, to use the processed encoder conversion table result. Ixx01 is then set up correspondingly for either a Y- or X- register.

If the Singleturn + Multiturn data fulfills 24 bits; $ST+MT \geq 24$ bits:

```
I183=$78B20    ; Motor 1 Commutation source address
I283=$78B24    ; Motor 2 Commutation source address
I383=$78B28    ; Motor 3 Commutation source address
I483=$78B2C    ; Motor 4 Commutation source address
I583=$78B30    ; Motor 5 Commutation source address
I683=$78B34    ; Motor 6 Commutation source address
I783=$78B38    ; Motor 7 Commutation source address
I883=$78B3C    ; Motor 8 Commutation source address

I101,8,100=3   ; Motors 1-8 Commutation Enabled, from Y-register
```

If the Singleturn + Multiturn data does not fulfill 24 bits; $ST+MT < 24$ bits:

```
I183=I104      ; Motor 1 Commutation source address
I283=I204      ; Motor 2 Commutation source address
I383=I304      ; Motor 3 Commutation source address
I483=I404      ; Motor 4 Commutation source address
I583=I504      ; Motor 5 Commutation source address
I683=I604      ; Motor 6 Commutation source address
I783=I704      ; Motor 7 Commutation source address
I883=I804      ; Motor 8 Commutation source address

I101,8,100=1   ; Motors 1-8 Commutation Enabled, from X-register
```

- **Technique 2/3**

With techniques 2 and 3, the commutation-dedicated encoder conversion table (see feedback setup section) result is the commutation source. And Ixx01 should be equal to 1 indicating an X-register:

```
// These addresses can differ depending on the encoder conversion table management
I183=$3512     ; Motor 1 Commutation source address -User Input
I283=$3514     ; Motor 2 Commutation source address -User Input
I383=$3516     ; Motor 3 Commutation source address -User Input
I483=$3518     ; Motor 4 Commutation source address -User Input
I583=$351A     ; Motor 5 Commutation source address -User Input
I683=$351C     ; Motor 6 Commutation source address -User Input
I783=$351E     ; Motor 7 Commutation source address -User Input
I883=$3520     ; Motor 8 Commutation source address -User Input

I101,8,100=1   ; Motors 1-8 Commutation Enabled, from X-register
```

Resolver

With resolvers, it is recommended to use the unfiltered data processed in the Encoder Conversion Table:

```
// these addresses can differ depending on the encoder conversion table management
I183=$3503     ; Motor 1 On-going Commutation Position Address
I283=$350B     ; Motor 2 On-going Commutation Position Address
I383=$3513     ; Motor 3 On-going Commutation Position Address
I483=$351B     ; Motor 4 On-going Commutation Position Address
I583=$3523     ; Motor 5 On-going Commutation Position Address
I683=$352B     ; Motor 6 On-going Commutation Position Address
I783=$3533     ; Motor 7 On-going Commutation Position Address
I883=$353B     ; Motor 8 On-going Commutation Position Address

I101,8,100=1   ; Motors 1-8 Commutation Enabled, from X-register
```

Yaskawa

With Yaskawa feedback devices, it is recommended to use the processed data in the Encoder Conversion Table (same as position):

```
I183=I104      ; Motor 1 On-going Commutation Position Address
I283=I204      ; Motor 2 On-going Commutation Position Address
I383=I304      ; Motor 3 On-going Commutation Position Address
I483=I404      ; Motor 4 On-going Commutation Position Address
I583=I504      ; Motor 5 On-going Commutation Position Address
I683=I604      ; Motor 6 On-going Commutation Position Address
I783=I704      ; Motor 7 On-going Commutation Position Address
I883=I804      ; Motor 8 On-going Commutation Position Address

I101,8,100=1   ; Motors 1-8 Commutation Enabled, from X-register
```

I2T Protection: Ixx57, Ixx58, Ixx69

The lower values (tighter specifications) of the continuous/instantaneous current ratings between the Geo Brick Drive and motor are chosen to setup I2T protection.

If the peak current limit chosen is that of the Geo Brick Drive (possible values 10, 16, or 30 Amps) then the time allowed at peak current is set to 2 seconds.
If the peak current limit chosen is that of the Motor, then the time allowed at peak is that of the motor (see spec sheet).

Examples:

- For setting up I2T on a 5/10-Amp Geo Brick Drive driving a 3/9-Amp motor, 3 amps continuous and 9 amps instantaneous will be used as current limits. And time allowed at peak is that of the motor.
- For setting up I2T on a 5/10-Amp Geo Brick Drive driving an 8/16-Amp motor, 5 amps continuous and 10 amps instantaneous will be used as current limits. And time allowed at peak is 2 seconds.
- For setting up I2T on a 15/30-Amp channel on a Geo Brick Drive driving a 12/45-Amp motor, 12 amps continuous and 30 amps instantaneous will be used as current limits. And Time allowed at peak is 2 seconds.

An 8-axis 5/10-Amp Geo Brick Drive driving eight 3/9-amp motors:

```
I15=0                            ; Trig Operations in Degrees
#define ServoClk        P7003    ; Servo Clock [KHz]—computed in Dominant Clock Settings Section
#define ContCurrent     3        ; Continuous Current Limit [Amps] -User Input
#define PeakCurrent     9        ; Instantaneous Current Limit [Amps] -User Input
#define MaxADC          16.26    ; =16.26 for 5/10A  -User Input, see electrical specs
                                 ; =26.02 for 8/16A  -User Input, see electrical specs
                                 ; =48.08 for 15/30A -User Input, see electrical specs
#define I2TOnTime       2        ; Time allowed at peak Current [sec] -User Input

I157=INT(32767*(ContCurrent*1.414/MaxADC)*cos(30))
I169=INT(32767*(PeakCurrent*1.414/MaxADC)*cos(30))
I158=INT((I169*I169- I157*I157)*ServoClk*1000*I2TOnTime/(32767*32767))

I257=I157      I258=I158      I269=I169
I357=I157      I358=I158      I369=I169
I457=I157      I458=I158      I469=I169
I557=I157      I558=I158      I569=I169
I657=I157      I658=I158      I669=I169
I757=I157      I758=I158      I769=I169
I857=I157      I858=I158      I869=I169
```

Note

This (software) I2T protection is handled by the PMAC to primarily protect the motor. The Geo Brick Drive has its own built-in hardware I2T as an additional layer of safety and self-protection.

Commutation Cycle Size: Ixx70, Ixx71

The ratio of Ixx70/Ixx71 represents the number of encoder counts per electrical cycle. These parameters are typically set up with respect to the motor, encoder type, resolution, and processing method:

For a rotary motor: the number of commutation cycles Ixx70 should be equal to the number of pole pairs: **Ixx70= {Number of pole pairs}.** The commutation cycle size **Ixx71**, is equal to the electrical cycle length or pole-pair pitch in units of encoder counts:

<table>
<tr><th>Feedback Type</th><th>Motor Scale Factor (SF)
[counts/rev]</th><th colspan="2">Ixx71</th></tr>
<tr><td>Quadrature</td><td>SF= Lines x 4</td><td colspan="2">= SF</td></tr>
<tr><td>Sinusoidal / HiperFace</td><td>SF= Sine/Cosine cycles per rev * 128</td><td colspan="2">= SF/32</td></tr>
<tr><td>Resolver</td><td>SF= 4096</td><td colspan="2">= SF*32= 131072</td></tr>
<tr><td rowspan="2">SSI / EnDat / BiSS
Technique 1</td><td rowspan="2">SF= 2^{ST}</td><td>= SF= 2^{ST}</td><td>If Ixx01= 3</td></tr>
<tr><td>= 32*SF= 32*2^{ST}</td><td>If Ixx01= 1</td></tr>
<tr><td>SSI / EnDat / BiSS
Technique 2</td><td>SF= 2^{ST-5} = 2^{ST} /32</td><td colspan="2" rowspan="2">= 2^{18}= 262144</td></tr>
<tr><td>SSI / EnDat / BiSS
Technique 3</td><td>SF= 2^{ST}</td></tr>
<tr><td>Yaskawa Sigma II</td><td>SF= 2^{ST}</td><td colspan="2">= 32*SF= 32*2^{ST}</td></tr>
</table>

Where ST: is the rotary encoder Singleturn resolution in bits

For a linear motor: the number of commutation cycles Ixx70 is typically equal to 1: **Ixx70=1**. The commutation cycle size **Ixx71**, is equal to the Electrical Cycle Length (ECL) or pole-pair pitch in units of encoder counts:

<table>
<tr><th>Feedback Type</th><th>Motor Scale Factor (SF)
[counts/mm]</th><th colspan="2">Ixx71</th></tr>
<tr><td>Quadrature</td><td>SF= $(1/RES_{mm})$*4</td><td colspan="2">= $SF*ECL_{mm}$= ECL_{mm} / RES_{mm}</td></tr>
<tr><td>Sinusoidal / HiperFace</td><td>SF= 128/RES_{mm}</td><td colspan="2">= $SF*ECL_{mm}$/32= 4* ECL_{mm} / RES_{mm}</td></tr>
<tr><td rowspan="2">SSI / EnDat / BiSS
Technique 1</td><td rowspan="2">SF= 1/RES_{mm}</td><td>= ECL_{mm} * SF= ECL_{mm} / RES_{mm}</td><td>If Ixx01= 3</td></tr>
<tr><td>= 32* ECL_{mm}*SF
= 32* ECL_{mm}/ RES_{mm}</td><td>If Ixx01= 1</td></tr>
<tr><td>SSI / EnDat / BiSS
Technique 2</td><td>SF= 1/(32*RES_{mm})</td><td colspan="2" rowspan="2">= ECL_{mm}*SF/2^{Offset}
= ECL_{mm}/(RES_{mm}*2^{Offset})</td></tr>
<tr><td>SSI / EnDat / BiSS
Technique 3</td><td>SF= 1/RES_{mm}</td></tr>
<tr><td>Yaskawa Sigma II</td><td>SF= 1/RES_{mm}</td><td colspan="2">= 32* ECL_{mm}*SF = 32* ECL_{mm}/ RES_{mm}</td></tr>
</table>

Where RES: is the linear scale resolution in user units (e.g. mm)
ECL: is the electrical cycle length of the linear motor in the same units as RES (e.g. mm)
Offset: is the ECT commutation offset; = linear encoder protocol bit length - 18

Note

The Singleturn (ST) data bits for rotary encoders, as well as the serial protocol bit-length for linear scales can be found in the encoder manufacturer's spec sheet.

Note

The Electrical Cycle Length (ECL) or pole-pair pitch (in user units) can be found in the motor manufacturer's spec sheet.

Ixx71 Saturation

High resolution encoders could saturate the Ixx71 register, which is a signed 24-bit register. Thus, the maximum value writeable to it is $2^{\wedge 24}-1_{\text{signbit}}$= 16,777,215.
But remember, the ratio of Ixx71/Ixx70 is what really matters. Dividing Ixx70 and Ixx71 by a common integer divisor could alleviate settings which are out of range.

Example: For an 8-pole brushless rotary motor, with a high resolution encoder (producing 33,554,432 counts/revolution), Ixx70 and Ixx71 are usually set to 4 (pole pairs), and 33554432 respectively. These settings are not acceptable since Ixx71 exceeds the maximum permissible value in its 24-bit register, dividing both Ixx70 and Ixx71 by 4 results in acceptable settings:
Ixx70= 4/4= 1
Ixx71= 33554432/4= 8388608

ADC Offsets: Ixx29, Ixx79

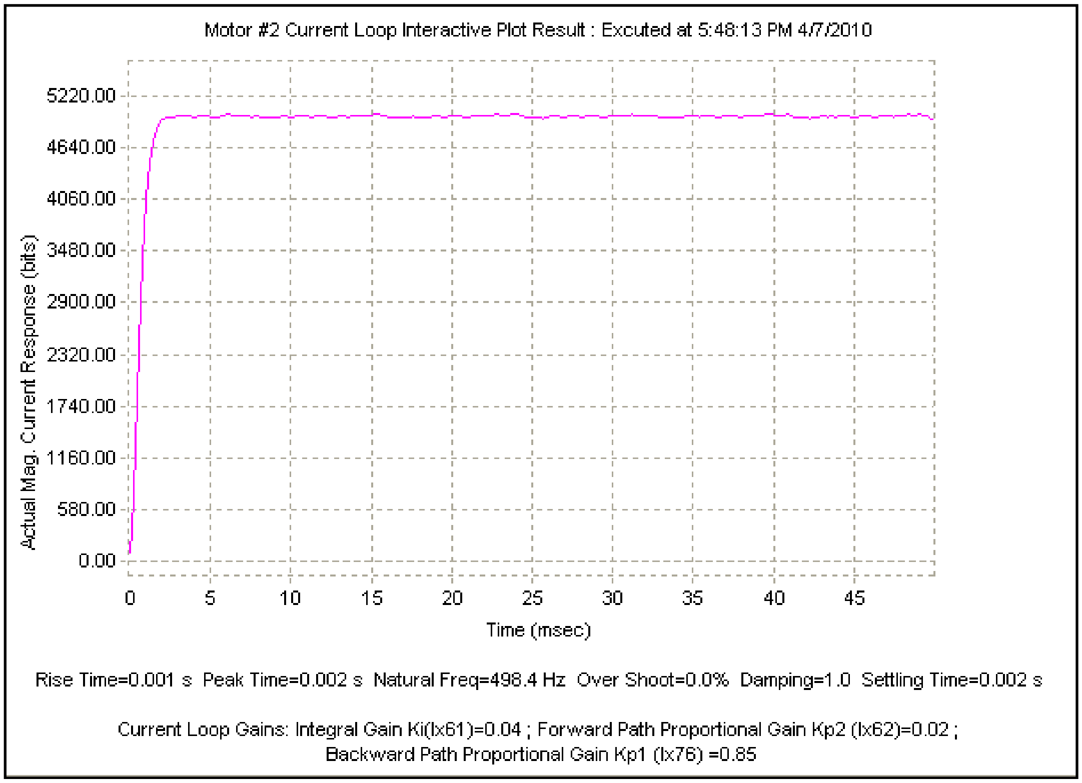
The ADC offsets importance may vary from one system to another, depending on the motor(s) type and application requirements. They can be left at default of zero especially if a motor setup is to be reproduced on multiple machines by copying the configuration file of the first time integration. However, they should ultimately be set to minimize measurement offsets from the A and B-phase current feedback circuits, respectively (read in Suggested M-variables Mxx05, Mxx06).

ADC offsets compensation can be done using the following procedure (starting from a killed motor). This can be implemented in a one-time test PLC:

1. Record the current loop tuning gains: Ixx61, Ixx62, and Ixx76. Then set them to zero, these will be restored at the end of the test.
2. Issue a #no0 (zero open loop output)
3. Sample ADC phases A, and B. Using suggested M-Variables Mxx05, and Mxx06 respectively. E.g. store snapshots in two separate arrays of P-Variable arrays.
4. Average readings over the number of sampled points.
5. Write the opposite value of the averaged ADCA readings in Ixx29
   Write the opposite value of the averaged ADCB readings in Ixx79
6. Issue a #nK (Kill motor)
7. Restore the original current loop gains.

Current-Loop Tuning: Ixx61, Ixx62, Ixx76

The current-loop tuning is done as in any Turbo PMAC digital current loop setup. The PMACTuningPro2 automatic or interactive utility can be used to fine-tune the Current-Loop. An acceptable Current-Loop step response would look like:



Note

Current-Loop Natural Frequencies in the range of 200-500 Hz are good enough for most applications. Tuning the current loop too tightly (Natural Frequency > 800Hz) could have deteriorating effects on the position loop tuning.

Motor Phasing, Power-On Mode: Ixx73, Ixx74, Ixx80, Ixx81, Ixx91

The Geo Brick Drive supports a variety of phasing procedures for commutated (brushless) motors. This section discusses the following phasing methods:

- **Manual | Custom Phasing**
- **2-Guess Phasing Method**
- **Stepper Phasing Method**
- **Hall Effect Phasing: Digital quadrature encoders**
- **Hall Effect Phasing: Yaskawa Incremental encoders**
- **Absolute Power-On Phasing: HiperFace**
- **Absolute Power-On Phasing: EnDat | SSI | BiSS**
- **Absolute Power-On Phasing: Yaskawa absolute encoders**

WARNING

An unreliable phasing search method can lead to a runaway condition. Test the phasing search method carefully to make sure it works properly under all conceivable conditions, and various locations of the travel. Make sure the Ixx11 fatal following error limit is active and as tight as possible so the motor will be killed quickly in the event of a serious phasing search error.

Note

In general, it is NOT recommended to execute any phasing search moves on power up using Turbo PMAC's automatic setting (Ixx80). Motor phasing should be inserted in a power-on plc before which it is ensured that the bus power has been applied.

Manual | Custom Phasing

Manual phasing can be used with virtually any type of feedback. It is ideal for:

- Quick Phasing
- Troubleshooting phasing difficulties
- Finding a “good” phase finding output value to use in the 2-guess or stepper phasing

Manual phasing consists of locking the motor tightly onto one of its phases, then zeroing the phase position register (suggested M-Variable Mxx71). When implemented properly (locking the motor tightly to a phase), it is considered to be one of the finest phasing methods.

The following is the most common manual phasing procedure:

1. Record the values of Ixx29, and Ixx79. These will be restored at the end of test.
2. Set Ixx29=0, and write a positive value in Ixx79
   Ixx79=500 is a good starting point for most motors.
3. Issue #nO0 where n is the motor number
4. Increase (for larger motors) or decrease (for smaller motors) Ixx79 as necessary until the motor is locked tightly onto one of its phases.
5. Wait for the motor to settle. In some instances, it oscillates around the phase for an extended period of time. Some motors are small enough that you could safely stabilize by hand.
6. Zero the phase position register , suggested M-variable Mxx71=0
7. Issue a #nK to kill the motor
8. Restore Ixx29, and Ixx79 to their original values
9. Clear the phasing search error bit, Suggested M-Variable Mxx48=0
10. The motor is now phased. It is ready for open loop or closed loop commands (if the position loop is tuned).

The aforementioned procedure can be done online from the terminal window, or implemented in a PLC for convenience.

Manual Phasing Example 1:

```
#define Mtr1PhasePos           M171    ; Motor 1 Phase Position Register, Suggested M-Variable
Mtr1PhasePos->X:$B4,0,24,S
#define Mtr1PhaseErrBit        M148    ; Motor 1 Phasing Search Error Bit, Suggested M-Variable
Mtr1PhaseErrBit->Y:$C0,8

Open plc 1 clear
I5111=500*8388608/I10 while(I5111>0) Endw
P129=I129 P179=I179    ; Store Ixx29, and Ixx79
I129=0 I179=1000       ; Set Ixx29=0 and Ixx79 to positive value (adjustable)
I5111=100*8388608/I10 while(I5111>0) Endw    ; 100 msec delay
CMD"#1o0"              ; Issue 0% open loop command output
I5111=3000*8388608/I10 while(I5111>0) Endw   ; 3 seconds delay to allow motor to settle
Mtr1PhasePos=0         ; Set phase register to zero
I5111=500*8388608/I10 while(I5111>0) Endw    ; 1/2 second delay
CMD"#1K"               ; Kill Motor
I5111=100*8388608/I10 while (I5111>0) Endw   ; 100 msec delay
I129=P129 I179=P179    ; Restore Ixx29 and Ixx79 to original values
Mtr1PhaseErrBit=0      ; Clear Phasing search error bit
I5111=500*8388608/I10 while (I5111>0) Endw   ; 1/2 second delay
Dis plc 1              ; Execute PLC once
Close
```

Alternately, a more refined manual phasing method can be implemented. Knowing a good value which would lock the motors onto a phase (using the above procedure), the following example locks (in small incremental steps) the motor onto one phase then steps it back into the other phase:

Manual Phasing Example 2:

```
#define Mtr1PhasePos          M171   ; Motor 1 Phase Position Register, Suggested M-Variable
Mtr1PhasePos->X:$B4,0,24,S
#define Mtr1PhaseErrBit       M148   ; Motor 1 Phasing Search Error Bit, Suggested M-Variable
Mtr1PhaseErrBit->Y:$C0,8

Open plc 1 clear
I5111=100*8388608/I10 while(I5111>0) Endw    ; Delay
P129=I129      P179=I179                     ; Store Ixx29, and Ixx79
I129=0         I179=0                        ; Set ADC offsets to zero

I5111=100*8388608/I10 while(I5111>0) Endw    ; Delay
CMD"#1o0"                                    ; Issue #nO0
I5111=100*8388608/I10 while(I5111>0) Endw    ; Delay

while (I129!>1500)                           ; Force motor to Phase A
 I129=I129+10  I179=0                        ; by pushing current incrementally
 I5111=100*8388608/I10 while(I5111>0) Endw   ; Delay
Endw
while (200 < ABS(M166))endw                  ; Wait for motor to settle
I5111=1000*8388608/I10 while(I5111>0) Endw   ; Delay

while (I179!>1500)                           ; Force motor to Phase B
 I179=I179+10  I129=I129-10                  ; by pushing current incrementally
 I5111=100*8388608/I10 while(I5111>0) Endw   ; Delay
Endw
while (200 < ABS(M166))endw                  ; Wait for motor to settle
I5111=1000*8388608/I10 while(I5111>0) Endw   ; Delay

Mtr1PhasePos=0                               ; Set phase position register to zero
I5111=250*8388608/I10 while(I5111>0) Endw    ; 1/2 second delay
CMD"#1K"                                     ; Kill Motor
I5111=100*8388608/I10 while (I5111>0) Endw   ; Delay
I129=P129 I179=P179                          ; Restore Ixx29 and Ixx79 to original values
Mtr1PhaseErrBit=0                            ; Clear Phasing search error bit
I5111=500*8388608/I10 while (I5111>0) Endw   ; Delay
Dis plc 1                                    ; Run PLC once
Close
```

2-Guess Phasing Method

The 2-guess is a rough phasing method for motors with relatively small loads. It is not ideal for high torque requirements. It can be used with any type of feedback. Example of typical settings:

Ixx73=1200 ; Phase finding output value (adjustable) in units of 16-bit DAC
Ixx74=12 ; Units of servo cycles (adjustable)
Ixx80=4 ; 2-guess method, no absolute position read, no power-on phasing

Stepper Phasing Method

The stepper is a finer phasing method than the 2-guess. It is generally used for motors with significant loads and higher torque demands. It can be used with any type of feedback. Example of typical settings:

Ixx73=1200 ; Phase finding output value (adjustable) in units of 16-bit DAC
Ixx74=80 ; Units of Servo Cycles * 256 (adjustable)
Ixx80=6 ; Stepper method, no absolute position read, no power-on phasing

Note

The 2-guess or stepper method(s) phase the motor upon issuing a #n$.

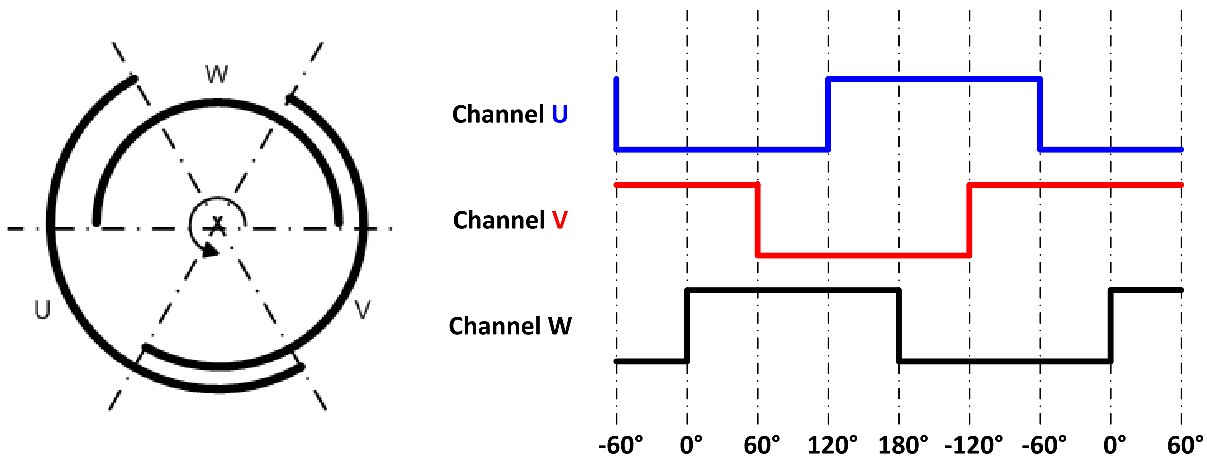
Hall Effect Phasing: Digital quadrature encoders

Digital hall sensors can be used for rough phasing on power-up without the need for a phasing search operation such as the manual, 2-guess, or stepper phasing methods. It provides absolute information about where the motor is positioned with respect to its commutation cycle. It is highly desirable due to the fact that it allows phasing the motor without any movement.

Note

Inherently, digital hall sensors have an error of about ±30°, resulting in a torque loss of about 15%. It needs to be corrected (fine phasing) for top operation.

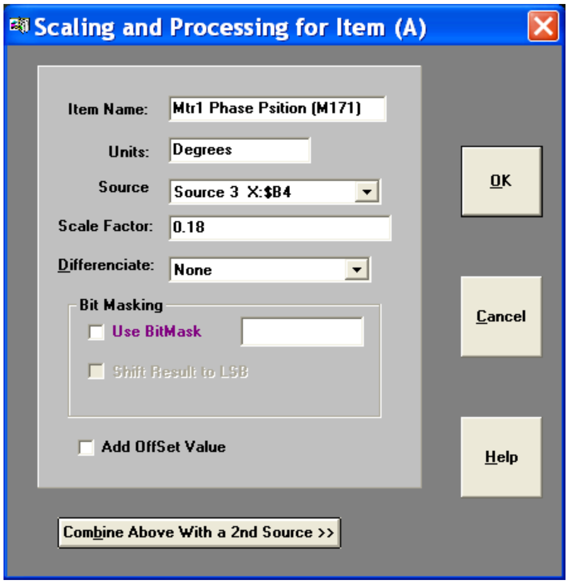
The Geo Brick Drive supports the conventional 120° spacing hall sensors' type, each nominally with 50% duty cycle, and nominally 1/3 cycle apart. The Geo Brick Drive has no automatic hardware or software features to work with 60° spacing. The 120° spacing format provides six distinct states per cycle:



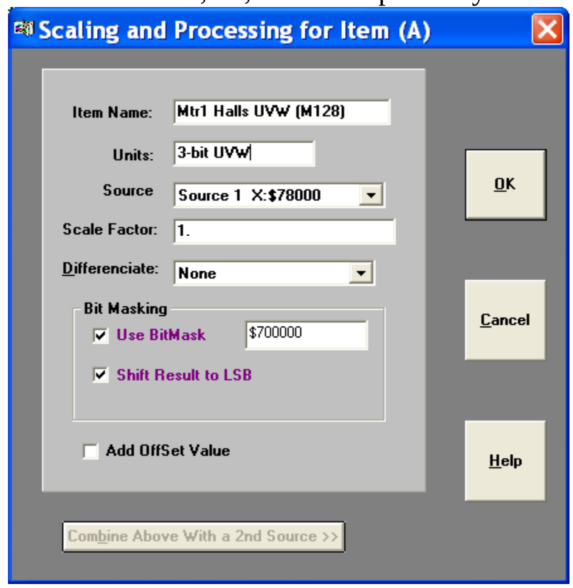
Follow these steps to implement hall sensor phasing:

1. Start with Ixx81=0, and Ixx91=0, which eventually are the parameters to be configured
2. Phase the motor manually or using the 2-guess/stepper method.
3. Jog the motor slowly (with rough PID gains), or move in open loop/by hand in the positive direction of the encoder while plotting Halls UVW (Mxx28) versus Phase Position (Mxx71).
4. Set up the detailed plot, scaling and processing for Halls UVW and Phase Position

Plotting the phase position (Mxx71)
The scale factor is used to scale the phase position to 0 - 360°. It is = 360 * Ixx70 / Ixx71

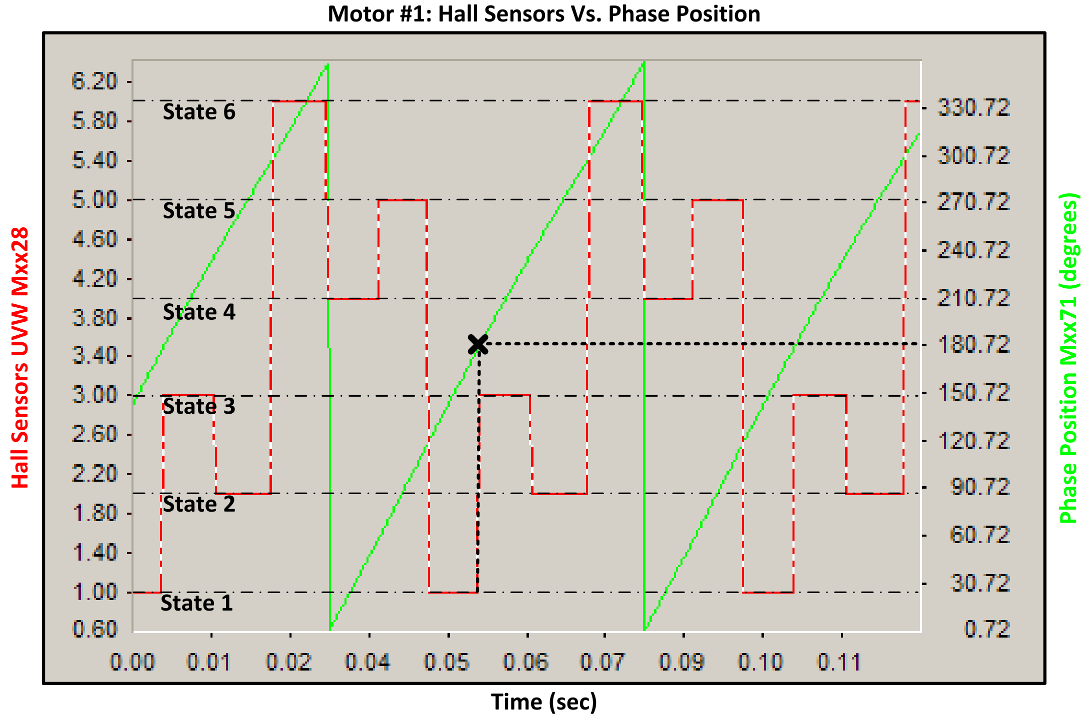


Plotting the hall sensors (Mxx28)
$700000 Masking enables reading W, V, and U in bits 20, 21, and 22 respectively



5. Gathering, and plotting data for a short travel of the motor should look like:

Motor #1: Hall Sensors Vs. Phase Position



Primarily, we are interested in two occurrences on the plot; the transition of the halls data between states 1 & 3, and the point of intersection of Mxx28 and Mxx71 at this transition. This represents the Hall Effect Zero (HEZ).

With **positive movement** of the motor, if the **halls state transition is from 1 to 3** (as seen in the example plot) then use the following set of equations:

```
I181=$78000                                 ; Channel 1 power-on phase address (see table below)
#define HallsTrans1_3  M7025                ; Standard direction, 1 to 3
#define Mtr1HEZ        P7025                ; Hall effect zero
#define Mtr1HEZTemp    P7026                ; Intermediate calculation
HallsTrans1_3->*                            ;
HallsTrans1_3=$800000                       ; Bit #22=0 for standard transition
Mtr1HEZ=180                                 ; Degrees - User Input
Mtr1HEZTemp = INT(((Mtr1HEZ%360)/360)*64)   ; Processing hall effect zero
I191=(Mtr1HEZTemp*65536)+HallsTrans1_3      ; Shift 16 bits left and set transition bit
```

With **positive movement** of the motor, if the **halls state transition is from 3 to 1** then use the following set of equations:

```
I181=$78000                                 ; Channel 1 power-on phase address (see table below)
#define HallsTrans3_1  M7025                ; Reversed direction, 3 to 1
#define Mtr1HEZ        P7025                ; Hall effect zero
#define Mtr1HEZTemp    P7026                ; Intermediate calculation
HallsTrans3_1->*                            ;
HallsTrans3_1=$C00000                       ; Bit #22=1 for reversed transition
Mtr1HEZ=180                                 ; Degrees - User Input
Mtr1HEZTemp = INT(((Mtr1HEZ%360)/360)*64)   ; Processing hall effect zero
I191=(Mtr1HEZTemp*65536)+HallsTrans3_1      ; Shift 16 bits left and set transition bit
```

Note

The only user input in the above set of equations is the Hall Effect Zero angle, derived from the plot.

Ixx81 addresses:

Power-On Phase Position Address Ixx81 For Hall Sensors			
Channel 1	$78000	Channel 5	$78000
Channel 2	$78008	Channel 6	$78008
Channel 3	$78010	Channel 7	$78010
Channel 4	$78018	Channel 8	$78018

Alternatively, the above procedure can be performed using the Halls Automatic Utility software available on our forum.

Note

The automatic software utility requires jogging the motor; make sure the motor is phased (custom, 2-guess, or stepper method) and that the position-loop tuning is acceptable for closed loop movement.

Fine Phasing

Correcting for hall sensors' error (torque loss) can be implemented using the following procedure (performed once per installation):

1. Phase the motor manually (as tight as possible). See manual phasing section.
2. Home motor to machine zero location (e.g. most commonly using flag and C-index), with or without home offset, similarly to how the motor would home after the machine has been commissioned.
3. Record the phase position Mxx71 at the home location

The above procedure reveals the optimum phase position at home or zero location of the motor. Subsequently, the motor is "roughly phased" on power up using hall sensors. And the phase position Mxx71 is then corrected (overwritten) after the motor is homed (to known location). This is usually done in a PLC routine.

Example:

Channel 1 is driving a motor with home capture done using home flag and index pulse (high true). The recorded phase position from the manual phasing reference test was found to be 330. It is stored (saved) in a user defined variable.

```
I7012=3          ; Motor 1 Capture Control, Index high and Flag high
I7013=0          ; Motor 1 Capture Control flag select, Home Flag

#define Mtr1DesVelZero        M133   ; Motor 1 Desired-velocity-zero bit, Suggested M-Variable
Mtr1DesVelZero->X:$0000B0,13,1       ;
#define Mtr1InPosBit          M140   ; Motor 1 Background in-position bit, Suggested M-Variable
Mtr1InPosBit->Y:$0000C0,0,1          ;
#define Mtr1PhasePos          M171   ; Motor 1 Phase Position Register, Suggested M-Variable
Mtr1PhasePos->X:$B4,0,24,S           ;
#define Mtr1RecPhasePos       P7027  ; Recorded Phase Position (Manual phasing reference test)
Mtr1RecPhasePos=330                  ; -- User Input

Open plc 1 clear
I5111=500*8388608/I10 while(I5111>0)Endw          ; 1/2 sec delay
CMD"#1$"                                          ; Phase motor, using Hall Effect Sensors
I5111=50*8388608/I10 while(I5111>0)Endw           ; 50 msec Delay
While(Mtr1DesVelZero=0 or Mtr1InPosBit=0) Endw    ; Wait until motor settles, and in position
CMD"#1hm"                                         ; Issue a home command
I5111=50*8388608/I10 while(I5111>0)Endw           ; 50 msec Delay
While(Mtr1DesVelZero=0 or Mtr1InPosBit=0)Endw     ; Wait until motor settles, and in position
Mtr1PhasePos =Mtr1RecPhasePos                     ; Adjust Phase Position
I5111=500*8388608/I10 while(I5111>0)Endw          ; 1/2 sec delay
CMD"#1K"                                          ; Kill Motor (Optional)
Disable plc 1                                     ; Execute once
Close
```

Hall Effect Phasing: Yaskawa Incremental encoders

Hall-effect sensors can be used for rough phasing on power-up without the need for a phasing search move. This initial phasing provides reasonable torque. With a hall sensors' error of about ±30° resulting a loss in torque of about 15%, it will need to be corrected for top operation.

Hall-effect sensors usually map out 6 zones of 60° electrical each. In terms of Turbo PMAC's commutation cycle, the boundaries should be at 180°, -120°, -60°, 0°, 60°, and 120°.

Zone	Definitions	Zone	Definitions

1	`#define Phase30Deg 1`
	`#define Phase90Deg 5`
	`#define Phase150Deg 4`
	`#define Phase210Deg 6`
	`#define Phase270Deg 2`
	`#define Phase330Deg 3`
		4	`#define Phase30Deg 4`
			`#define Phase90Deg 6`
			`#define Phase150Deg 2`
			`#define Phase210Deg 3`
			`#define Phase270Deg 1`
			`#define Phase330Deg 5`

2	`#define Phase30Deg 2`
	`#define Phase90Deg 3`
	`#define Phase150Deg 1`
	`#define Phase210Deg 5`
	`#define Phase270Deg 4`
	`#define Phase330Deg 6`
		5	`#define Phase30Deg 5`
			`#define Phase90Deg 4`
			`#define Phase150Deg 6`
			`#define Phase210Deg 2`
			`#define Phase270Deg 3`
			`#define Phase330Deg 1`

3	`#define Phase30Deg 3`
	`#define Phase90Deg 1`
	`#define Phase150Deg 5`
	`#define Phase210Deg 4`
	`#define Phase270Deg 6`
	`#define Phase330Deg 2`
		6	`#define Phase30Deg 6`
			`#define Phase90Deg 2`
			`#define Phase150Deg 3`
			`#define Phase210Deg 1`
			`#define Phase270Deg 5`
			`#define Phase330Deg 4`

In order to decide which set of definitions to use for a motor, a one time test needs to be done. It consists of forcing/locking the motor to a phase with a current offset and reading the state output of the hall sensors.

- Record the values of Ixx29, and Ixx79 to restore them at the end of test
- Set Ixx29=0, write a positive value to Ixx79 and issue a #nO0. 500 is a reasonable value for Ixx79 to start with. Increment as necessary to force the motor to tightly lock onto a phase.
- Record the Yaskawa Incremental Sensors Data. The result is an integer number between 1 and 6 (a value of 0 or 7 is not valid) representing the zone of which definitions to be used in the subsequent PLC. Remember, Turbo PMAC allows only nibble based register definitions, so in order to read bits 1 thru 3, a 1-bit right shift or division by 2 is necessary:

```
#define Ch1YasIncBits0_3       M127    ; Channel 1 Yaskawa Inc. Data (first 4 bits)
#define Ch2YasIncBits0_3       M227    ; Channel 2 Yaskawa Inc. Data (first 4 bits)
#define Ch3YasIncBits0_3       M327    ; Channel 3 Yaskawa Inc. Data (first 4 bits)
#define Ch4YasIncBits0_3       M427    ; Channel 4 Yaskawa Inc. Data (first 4 bits)
#define Ch5YasIncBits0_3       M527    ; Channel 5 Yaskawa Inc. Data (first 4 bits)
#define Ch6YasIncBits0_3       M627    ; Channel 6 Yaskawa Inc. Data (first 4 bits)
#define Ch7YasIncBits0_3       M727    ; Channel 7 Yaskawa Inc. Data (first 4 bits)
#define Ch8YasIncBits0_3       M827    ; Channel 8 Yaskawa Inc. Data (first 4 bits)

Ch1YasIncBits0_3->Y:$78B20,0,4
Ch2YasIncBits0_3->Y:$78B24,0,4
Ch3YasIncBits0_3->Y:$78B28,0,4
Ch4YasIncBits0_3->Y:$78B2C,0,4
Ch5YasIncBits0_3->Y:$78B30,0,4
Ch6YasIncBits0_3->Y:$78B34,0,4
Ch7YasIncBits0_3->Y:$78B38,0,4
Ch8YasIncBits0_3->Y:$78B3C,0,4
#define Ch1YasIncHalls         M128
#define Ch2YasIncHalls         M228
#define Ch3YasIncHalls         M328
#define Ch4YasIncHalls         M428
#define Ch5YasIncHalls         M528
#define Ch6YasIncHalls         M628
#define Ch7YasIncHalls         M128
#define Ch8YasIncHalls         M828
M128,8,100->*

Ch1YasIncHalls=Ch1YasIncBits0_3/2     ; Channel 1 Yaskawa Inc. Hall Sensors Data
Ch2YasIncHalls=Ch2YasIncBits0_3/2     ; Channel 2 Yaskawa Inc. Hall Sensors Data
Ch3YasIncHalls=Ch3YasIncBits0_3/2     ; Channel 3 Yaskawa Inc. Hall Sensors Data
Ch4YasIncHalls=Ch4YasIncBits0_3/2     ; Channel 4 Yaskawa Inc. Hall Sensors Data
Ch5YasIncHalls=Ch5YasIncBits0_3/2     ; Channel 5 Yaskawa Inc. Hall Sensors Data
Ch6YasIncHalls=Ch6YasIncBits0_3/2     ; Channel 6 Yaskawa Inc. Hall Sensors Data
Ch7YasIncHalls=Ch7YasIncBits0_3/2     ; Channel 7 Yaskawa Inc. Hall Sensors Data
Ch8YasIncHalls=Ch8YasIncBits0_3/2     ; Channel 8 Yaskawa Inc. Hall Sensors Data
```

- Restore Ixx29, and Ixx79 to their original values

Example:
Channel 1 is driving a Yaskawa Incremental Encoder, with the test procedure above resulting in zone-1 definitions. Halls power-on phasing can be done in a PLC as follows:

```
#define Ch1IncData       M7030
#define Ch1Halls         M7031

Ch1IncData->Y:$78B20,0,24
Ch1Halls->*

#define Mtr1PhasePos      M171       ; Suggested M-Variable definition
#define Mtr1PhaseSrchErr  M148       ; Suggested M-Variable definition

Mtr1PhasePos->X:$0000B4,24,S         ; #1 Present phase position (counts *Ixx70)
Mtr1PhaseSrchErr->Y:$0000C0,8,1      ; #1 Phasing error fault bit

// Zone-1 Definitions  -User Input
#define Phase30Deg        1
#define Phase90Deg        5
#define Phase150Deg       4
#define Phase210Deg       6
#define Phase270Deg       2
#define Phase330Deg       3

Open plc 1 clear
Ch1Halls = int ((Ch1IncData & $E) / 2);
If (Ch1Halls = Phase30Deg)
   Mtr1PhasePos = I171 * 30 / 360;
Endif
If (Ch1Halls = Phase90Deg)
   Mtr1PhasePos = I171 * 90 / 360;
Endif
If (Ch1Halls = Phase150Deg)
   Mtr1PhasePos = I171 * 150 / 360;
Endif
If (Ch1Halls = Phase210Deg)
   Mtr1PhasePos = I171 * 210 / 360;
Endif
If (Ch1Halls = Phase270Deg)
   Mtr1PhasePos = I171 * 270 / 360;
Endif
If (Ch1Halls = Phase330Deg)
   Mtr1PhasePos = I171 * 330 / 360;
Endif
Mtr1PhaseSrchErr = 0;
disable plc 1
close
```

Absolute Power-On Phasing: HiperFace

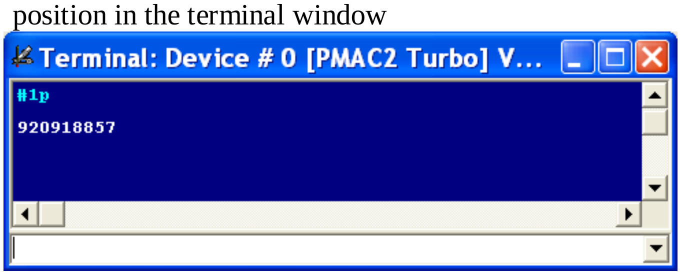
With HiperFace, the absolute serial data can be used to establish a phase reference position on power-up without moving the motor. A custom PLC is suggested for reading the absolute power-on position directly from the raw serial HiperFace data registers.

Note

Prior to implementing a power-on phasing routine, the user should verify that the motor can be phased manually, be able to execute open-loop moves successfully (output and encoder direction matching), and possibly perform jog commands (requires PID tuning).

A one-time simple test (per installation) is performed, preferably on an unloaded motor, to find the motor phase position offset:

1. Execute the power-position read PLC to ensure that the actual position is correct and up to date
2. Record the values of Ixx29, and Ixx79 to restore them at the end of test (if applicable)
3. Set Ixx29=0, and write a positive value to Ixx79 then issue a #nO0 (where n is the motor number). 500 is a conservative value for Ixx79 to start with. Adjust appropriately (most likely to increase) to force the motor to lock tightly onto a phase
4. Wait for the motor to settle
5. Record the absolute position from the position window or issue a #nP to return the motor position in the terminal window



6. Issue a #nK to kill the motor
7. Restore Ixx29, and Ixx79 to their original values (if applicable)
8. Enter the recorded value in the corresponding motor/channel definition in the example plc below

The following example PLC computes and corrects for the phase position register (Mxx71) for channels 1 through 8. It is pre-configured for the user to input their encoder/motor information, also to specify which channels are to perform an absolute power-on phasing.

Using The Absolute Power-On Phasing Example PLC

Under the User Input section:

1. In MtrxSF, enter the motor scale factor.
   For rotary encoders, this is the number of counts per revolution = $2^{\text{Single-Turn Resolution}}$
   For Linear encoders, this is the number of counts per user units (i.e. mm) = 1/Encoder Resolution

2. In MtrxPhaseTest, enter the position value recorded in the manual phasing test described above.

3. In ChPhaseSel, specify which channels are desired to perform an absolute power-on phasing. This value is in hexadecimal. A value of 1 in the corresponding field specifies that this channel is connected, 0 specifies that it is not connected and should not perform phasing. Examples:

Absolute Power-On Phasing, channels 1 through 4

Channel#	8	7	6	5	4	3	2	1
ChPhaseSel (Binary)	0	0	0	0	1	1	1	1
ChPhaseSel (Hex)	0				F			

=> **ChPhaseSel =$0F**

Absolute Power-On Phasing, channels 1,3,5,7

Channel#	8	7	6	5	4	3	2	1
ChPhaseSel (Binary)	0	1	0	1	0	1	0	1
ChPhaseSel (Hex)	5				5			

=> **ChPhaseSel =$55**

```
//=========================== NOTES ABOUT THIS PLC EXAMPLE ================================//
// This PLC example utilizes: - P7050 through P7079
//                            - Suggested M-Variables (make sure they are downloaded)
// Make sure that current and/or future configurations do not create conflicts with
// these parameters.
//=========================================================================================//

P7050..7079=0  ; Reset P-Variables at download

//==================================== USER INPUT =========================================//
#define Mtr1SF P7050   #define Mtr5SF P7054   ; Motors scale factor
#define Mtr2SF P7051   #define Mtr6SF P7055   ; cts/rev for rotary encoders
#define Mtr3SF P7052   #define Mtr7SF P7056   ; cts/user units (i.e. mm, inches) for linear
#define Mtr4SF P7053   #define Mtr8SF P7057   ;
Mtr1SF=0       Mtr5SF=0       ; --User Input
Mtr2SF=0       Mtr6SF=0       ; --User Input
Mtr3SF=0       Mtr7SF=0       ; --User Input
Mtr4SF=0       Mtr8SF=0       ; --User Input

#define Mtr1PhaseTest P7058   #define Mtr5PhaseTest P7062   ; Phase force test values
#define Mtr2PhaseTest P7059   #define Mtr6PhaseTest P7063   ;
#define Mtr3PhaseTest P7060   #define Mtr7PhaseTest P7064   ;
#define Mtr4PhaseTest P7061   #define Mtr8PhaseTest P7065   ;
Mtr1PhaseTest=0 Mtr5PhaseTest=0       ; --User Input
Mtr2PhaseTest=0 Mtr6PhaseTest=0       ; --User Input
Mtr3PhaseTest=0 Mtr7PhaseTest=0       ; --User Input
Mtr4PhaseTest=0 Mtr8PhaseTest=0       ; --User Input

#define ChPhaseSel P7066      ; Select channels to perform power-on phasing (in Hexadecimal)
ChPhaseSel=$0                 ; Channels selected for power-on phasing --User Input

//================================ DEFINITIONS & SUBSTITUTIONS ============================//
#define ChNo           P7067  ; Present addressed channel
#define PhaseOffset    P7068  ; Holding register for computing phase position offset
#define ActPos         P7069  ; Indirect addressing index for actual position, 162
#define PresPhasePos   P7070  ; Holding register for computing present phase position
#define Ixx70          P7071  ; Indirect addresssing index for No of commutation cycles, 170
#define Ixx71          P7072  ; Indirect addresssing index for commutation cycle size, 171
#define Mxx71          P7073  ; Indirect addresssing index for phase position register, 171
#define PhaseErrBit    P7074  ; Indirect addresssing index for phasing search error bit, 148
#define PhaseTest      P7075  ; Indirect addresssing index for force phase test values, 7058
#define MtrSF          P7076  ; Indirect addresssing index for motor scale factor, 7050
#define ChNoHex        P7077  ; Channel number in hex
#define Ixx08          P7078  ; Indirect addresssing index for position scale factor, 108
#define ChPhaseTrue    P7079  ; Present channel power-on phasing flag, =1 true =0 false

//==================================== PLC SCRIPT CODE ====================================//
Open plc 1 clear
ChNo=0         ; Reset channel number
While(ChNo!>7) ; Loop for 8 channels
 ChNo=ChNo+1
 ChNoHex=exp((ChNo-1)*ln(2))
 ChPhaseTrue=(ChPhaseSel&ChNoHex)/ChNoHex
 If (ChPhaseTrue!=0)   ; Absolute read on this channel?
  MtrSF=7050+(ChNo-1)*1
  PhaseTest=7058+(ChNo-1)*1
  Ixx70=170+(ChNo-1)*100
  Ixx71=171+(ChNo-1)*100
  ActPos=162+(ChNo-1)*100
```

```
  Ixx08=108+(ChNo-1)*100
  Mxx71=171+(ChNo-1)*100
  PhaseErrBit=148+(ChNo-1)*100
  I5111= 100*8388608/I10 while(I5111>0) endw
  // Compute position offset from user force phase test input
  PhaseOffset=P(PhaseTest)%P(MtrSF)
  PhaseOffset=PhaseOffset*I(Ixx70)
  PhaseOffset=PhaseOffset%I(Ixx71)
  I5111= 100*8388608/I10 while(I5111>0) endw
  // Compute present phase position
  PresPhasePos=M(ActPos)/(I(Ixx08)*32)
  PresPhasePos=PresPhasePos%P(MtrSF)
  PresPhasePos=PresPhasePos*I(Ixx70)
  PresPhasePos=PresPhasePos%I(Ixx71)
  I5111= 100*8388608/I10 while(I5111>0) endw
  // Correct for Mxx71 to apply power-on phasing, and clear phase error search bit
  M(Mxx71)=(PresPhasePos-PhaseOffset)%I(Ixx71)
  M(PhaseErrBit)=0
  I5111= 100*8388608/I10 while(I5111>0) endw
 EndIf
Endw
Dis plc 1
close
//===========================================================================================//
```

Absolute Power-On Phasing: EnDat | SSI | BiSS

With absolute serial encoders, the absolute serial data can be used to establish a phase reference position on power-up without moving the motor or executing a phase search move.

The automatic setup of power-on phasing with PMAC is established through finding the motor's phase offset (a one-time test per installation) and storing the result (scaled properly) in the phase position offset register (Ixx75). It also requires specifying the power-on phase source (Ixx81), and format (Ixx91).

The following, is a summary of the settings with the various proposed setup techniques:

	Technique 1		**Technique 2/3 (Ixx01=1)**
	For Ixx01= 3	**For Ixx01= 1**	
PhaseOffset (found experimentally)	Read from Serial data register A	Read from Position ECT result	Read from Commutation ECT result
Ixx81	= Serial data register A	= Ixx83 (Pos. ECT result)	= Comm. ECT result
Ixx91	= Unsigned, Y-register ST bits	= Unsigned, X-register, (ST + 5bit shift) bits	= Unsigned, X-register, 18 bits
Ixx75	= (- PhaseOffset * Ixx70) % Ixx71		

Note

The automatic power-on phasing routine (Ixx75, Ixx81, and Ixx91) expects the least significant bit of the data to be right most shifted (at bit 0).

Remember that the serial data register A address for each of the channels is:

Serial Data Register A			
Channel 1	Y:$78B20	Channel 5	Y:$78B30
Channel 2	Y:$78B24	Channel 6	Y:$78B34
Channel 3	Y:$78B28	Channel 7	Y:$78B38
Channel 4	Y:$78B2C	Channel 8	Y:$78B3C

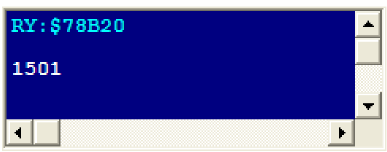
Caution

Prior to implementing an absolute power-on phasing routine, make sure that the motor can be phased manually, and that open-loop and/or closed-loop moves (require PID tuning) can be performed successfully.

Finding the Phase Offset

The phase offset is found experimentally by performing a one-time phase force test on an uncoupled/unloaded (preferably) motor:

1. Read/update the absolute position (must be read correctly for the phasing to work).
   Issue a #n$* command, or enable the corresponding absolute position read PLC.
2. Record Ixx29, and Ixx79 (if non zero).These should be restored at the end of the test
3. Set Ixx29=0, and write a positive value to Ixx79 (500 is a good starting value).
4. Issue a #nO0 to send a zero open loop output.
5. Increase Ixx79 until the motor is tightly locked onto a phase.
6. Make sure the motor is settled and stationary (locked onto a phase)
7. Record the following value (this is the motor's phase offset):

Technique 1		**Technique 2/3**
For Ixx01=3	**For Ixx01=1**	
Query the motor's corresponding serial data register A e.g. RY:$78B20	Query the motor's corresponding position ECT result e.g.: RX:$3502	Query the motor's corresponding commutation ECT result e.g.: RX:$3512
		

8. Issue a #nK to kill the motor
9. Restore Ixx29, and Ixx79 to their original values

Setting up Ixx81, the power-on phase position address:

Technique 1		**Technique 2/3 (Ixx01=1)**
For Ixx01= 3	**For Ixx01= 1**	
= Serial data register A	= Ixx83 (Pos. ECT result)	= Comm. ECT result

- Technique 1:

If Ixx01= 3; Ixx81 is equal to the motor's corresponding serial data register A. (e.g.: I181=$78B20).
If Ixx01=1; Ixx81 is equal to the motor's corresponding position ECT result. (e.g.: I181=$3502).

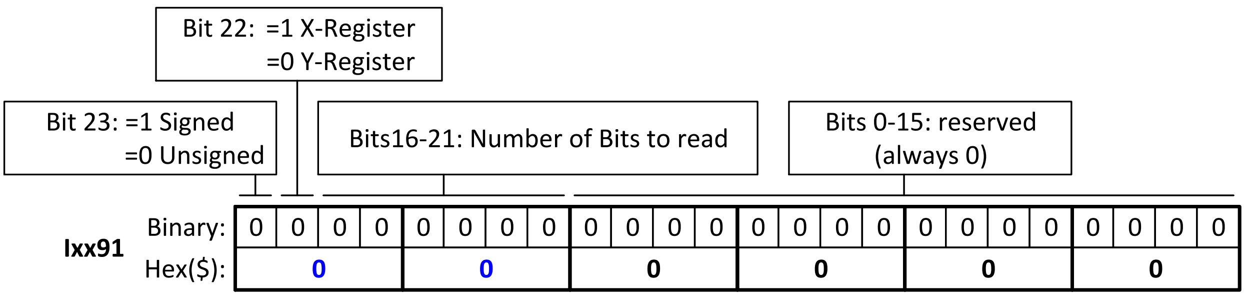
- Technique 2/3:

Ixx81 is equal to the motor's corresponding commutation ECT result. (e.g.: I181=$3512).

Setting up Ixx91, the power-on phase position format:

Technique 1		Technique 2/3 (Ixx01=1)
For Ixx01= 3	**For Ixx01= 1**	
= Unsigned, Y-register ST bits	= Unsigned, X-register, (ST + 5bit-shift) bits	= Unsigned, X-register, 18 bits

The following diagram displays how Ixx91 is set up:



- Technique 1:

If Ixx01=3;   Ixx91 is set up for unsigned, Y-register, Singleturn bits.
For example: A 30-bit (18-bit Singleturn, 12-bit Multiturn) rotary encoder would yield Ixx91= $120000.

If Ixx01=1;   Ixx91 is set up for unsigned, X-register, (Singleturn +5) bits.
For example: A 20-bit (20-bit Singleturn, 0-bit Multiturn) rotary encoder, or linear scale with similar protocol resolution (20 bits) would yield Ixx91= $590000.

- Technique 2/3:

Since the commutation is limited to 18 bits, and processed separately in the encoder conversion table, Ixx91 is always= $520000 (unsigned, X-register, 18 bits).

Note

Ixx91 is a 24-bit hexadecimal word. The upper most two digits are the only relevant ones. The lower 16 bits are reserved and should always be left at zero.

Setting up Ixx75, the phase position offset

The Phase position offset is set up using the following equation:

$$Ixx75 = (-\ PhaseOffset \times Ixx70)\ \%\ Ixx71$$

Where: PhaseOffset is the recorded value (found earlier) from the phase force test.

In this mode, and upon issuing a #n$ command, PMAC will compute the correct phase position then close the loop on the motor (motor must be tuned to hold position).

Caution

It is imperative that the absolute position read is performed successfully prior to issuing a phase command.

If closing the position loop is not desired with the #n$ command then it is advised to create a simple PLC, in which the current and PID loop gains are set to zero prior to issuing #n$ then restored (and motor killed) after the phase position has been set, e.g.:

```
Open PLC 1 Clear
// Make sure that the absolute position is read and reported prior to this script code
I5111=100*8388608/I10 While(I5111>0) Endw    ; 100 msec delay
CMD"#1K"                                     ; Make sure motor is killed
I5111=100*8388608/I10 While(I5111>0) Endw    ; 100 msec delay
CMD"I130..139=0"                             ; Zero PID loop gains
I161=0 I162=0 I176=0                         ; Zero Current loop gains
I5111=100*8388608/I10 While(I5111>0) Endw    ; 100 msec delay
CMD"#1$"                                     ; Phase command
I5111=500*8388608/I10 While(I5111>0) Endw    ; 500 msec delay
CMD"#1K"                                     ; Kill Motor
I5111=500*8388608/I10 While(I5111>0) Endw    ; 500 msec delay
// Here: ok to restore PID and current loop gains
// I130=X I131=X I132=X I133=X I134=X I135=X I136=X I137=X I138=X I139=X
// I161=X I162=X I176=X
I5111=100*8388608/I10 While(I5111>0) Endw    ; 100 msec delay
Dis PLC 1
Close
```

Absolute Power-On Phasing: Yaskawa absolute encoders

With absolute encoders, the single turn data is used to find an absolute phase position offset per electrical cycle thus an absolute phase reference position.

Note

Prior to implementing a power-on phasing routine you should try and be able to phase the motor manually, successfully execute open-loop moves (output and encoder direction matching), and jog commands (require PID tuning). Remember to increase the fatal following error limit with high resolution encoders when executing closed-loop moves

The U-phase in the Yaskawa motor/encoder assemblies is usually aligned with the index pulse, which should result in the same motor phase offset per one revolution for each encoder type (i.e. 16, 17, or 20-bit).

Yaskawa Absolute Encoders Single-Turn Data		
16-bit	17-bit	20-bit
#define Mtr1STD4_15 M180	#define Mtr1STD0_23 M180	#define Mtr1STD4_23 M180
#define Mtr2STD4_15 M280	#define Mtr2STD0_23 M280	#define Mtr2STD4_23 M280
#define Mtr3STD4_15 M380	#define Mtr3STD0_23 M380	#define Mtr3STD4_23 M380
#define Mtr4STD4_15 M480	#define Mtr4STD0_23 M480	#define Mtr4STD4_23 M480
#define Mtr5STD4_15 M580	#define Mtr5STD0_23 M580	#define Mtr5STD4_23 M580
#define Mtr6STD4_15 M680	#define Mtr6STD0_23 M680	#define Mtr6STD4_23 M680
#define Mtr7STD4_15 M780	#define Mtr7STD0_23 M780	#define Mtr7STD4_23 M780
#define Mtr8STD4_15 M880	#define Mtr8STD0_23 M880	#define Mtr8STD4_23 M880
Mtr1STD4_15->Y:$278B20,4,16	Mtr1STD0_23->Y:$278B20,0,24	Mtr1STD4_23->Y:$278B20,4,20
Mtr2STD4_15->Y:$278B24,4,16	Mtr2STD0_23->Y:$278B24,0,24	Mtr2STD4_23->Y:$278B24,4,20
Mtr3STD4_15->Y:$278B28,4,16	Mtr3STD0_23->Y:$278B28,0,24	Mtr3STD4_23->Y:$278B28,4,20
Mtr4STD4_15->Y:$278B2C,4,16	Mtr4STD0_23->Y:$278B2C,0,24	Mtr4STD4_23->Y:$278B2C,4,20
Mtr5STD4_15->Y:$278B20,4,16	Mtr5STD0_23->Y:$278B20,0,24	Mtr5STD4_23->Y:$278B20,4,20
Mtr6STD4_15->Y:$278B34,4,16	Mtr6STD0_23->Y:$278B34,0,24	Mtr6STD4_23->Y:$278B34,4,20
Mtr7STD4_15->Y:$278B38,4,16	Mtr7STD0_23->Y:$278B38,0,24	Mtr7STD4_23->Y:$278B38,4,20
Mtr8STD4_15->Y:$278B3C,4,16	Mtr8STD0_23->Y:$278B3C,0,24	Mtr8STD4_23->Y:$278B3C,4,20

A one-time simple test (per installation) is performed on an unloaded motor to find the motor phase position offset:

- Enable the Absolute position read PLC. Previously created in the feedback section.
- Record the values of Ixx29, and Ixx79 to restore them at the end of test.
- Set Ixx29=0, and write a positive value to Ixx79 then issue a #nO0. 500 is a reasonably conservative value for Ixx79 to start with. Adjust appropriately (most likely increase) to force the motor (unloaded) to lock tightly onto a phase.
- Record the Single-Turn Data value (defined in the table above) and store in the user defined motor phase offset.
- Issue a #nK to kill the motor
- Restore Ixx29, and Ixx79 to their original values

Yaskawa Absolute Encoders Motor Phase Offset (found from above test procedure)		
16-bit	17-bit	20-bit
#define PhaseOffset_16Bit P184	#define PhaseOffset_17Bit P184	#define PhaseOffset_20Bit P184
PhaseOffset_16Bit=5461	PhaseOffset_17Bit=10922	PhaseOffset_20Bit=30000

Note

Appropriate masking is required with 17-bit encoders to process the data correctly.

Absolute Power-On Phasing Example PLCs (Yaskawa):

With the motor phase position offset established, the phase position register can now be modified on power-up to compensate for the calculated offset. This allows the user to issue jog commands or close the loop and run a motion program on power-up or reset.

Channel 1 driving a 16-bit Yaskawa absolute encoder

```
#define Mtr1PhasePos          M171   ; Suggested M-Variables
Mtr1PhasePos->X:$B4,24,S
#define Mtr1PhaseErr          M148   ; Suggested M-Variables
Mtr1PhaseErr->Y:$C0,8
#define Mtr1CommSize          I171   ;
#define Mtr1CommCycles        I170   ;
#define Mtr1CommRatio         P170   ; Motor 1 commutation cycle size (Ixx71/Ixx70 counts)
Mtr1CommRatio=Mtr1CommSize/Mtr1CommCycles

Open plc 1 clear
Mtr1PhasePos = ((Mtr1STD4_15 % Mtr1CommRatio) - PhaseOffset_16Bit) * 32 * Mtr1CommCycles
Mtr1PhaseErr = 0
Disable plc 1
Close
```

Channel 1 driving a 17-bit Yaskawa absolute encoder

```
#define Mtr1PhasePos          M171   ; Suggested M-Variables
Mtr1PhasePos->X:$B4,24,S
#define Mtr1PhaseErr          M148   ; Suggested M-Variables
Mtr1PhaseErr->Y:$C0,8
#define Mtr1CommSize          I171
#define Mtr1CommCycles        I170
#define Mtr1CommRatio         P170   ; Motor 1 commutation cycle size (Ixx71/Ixx70 counts)
Mtr1CommRatio=Mtr1CommSize/Mtr1CommCycles

Open plc 1 clear
Mtr1PhasePos = ((Int((Mtr1STD0_23&$1FFFF0)/$F) % Mtr1CommRatio) - PhaseOffset_17Bit) * 32 *
Mtr1CommCycles
Mtr1PhaseErr = 0
Disable plc 1
Close
```

Channel 1 driving a 20-bit Yaskawa absolute encoder

```
#define Mtr1PhasePos          M171   ; Suggested M-Variables
Mtr1PhasePos->X:$B4,24,S
#define Mtr1PhaseErr          M148   ; Suggested M-Variables
Mtr1PhaseErr->Y:$C0,8
#define Mtr1CommSize          I171
#define Mtr1CommCycles        I170
#define Mtr1CommRatio         P170   ; Motor 1 commutation cycle size (Ixx71/Ixx70 counts)
Mtr1CommRatio=Mtr1CommSize/Mtr1CommCycles

#define TwoToThe20th          1048576

Open plc 1 clear
If (Mtr1STD4_23 !< PhaseOffset_20Bit)
   Mtr1PhasePos = (Mtr1STD4_23 - PhaseOffset_20Bit) * 32
Else
   Mtr1PhasePos = (TwoToThe20th - PhaseOffset_20Bit + Mtr1STD4_23) * 32
EndIf
Mtr1PhaseErr = 0;
Disable plc 1
Close
```

Note

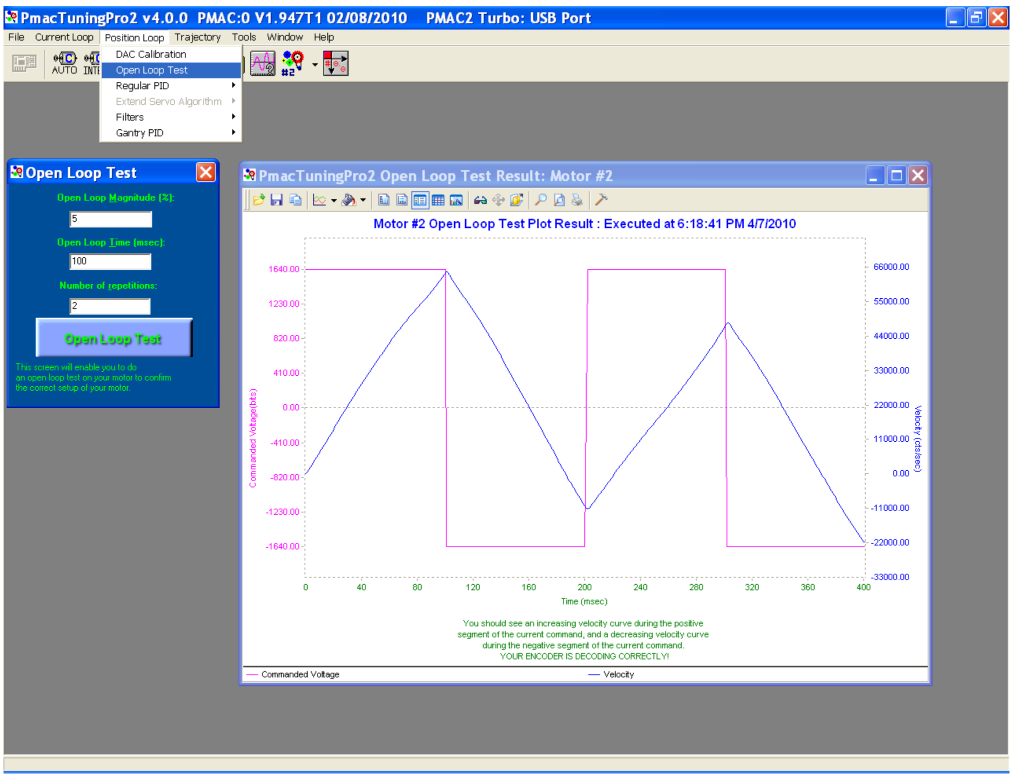
It is highly recommended to try the sequence in this PLC manually at first (using the terminal window). In some cases, the Motor Phase Position Offset has to be added instead of subtracted depending on the direction of the encoder mounting/decoding. Turbo PMAC has no control on the direction of serial encoder data

Open-Loop Test, Encoder Decode: I7mn0

Having phased the motor successfully, it is now possible to execute an open loop test. The open-loop test is critical to verify that the direction sense of the encoder is the same as the command output.

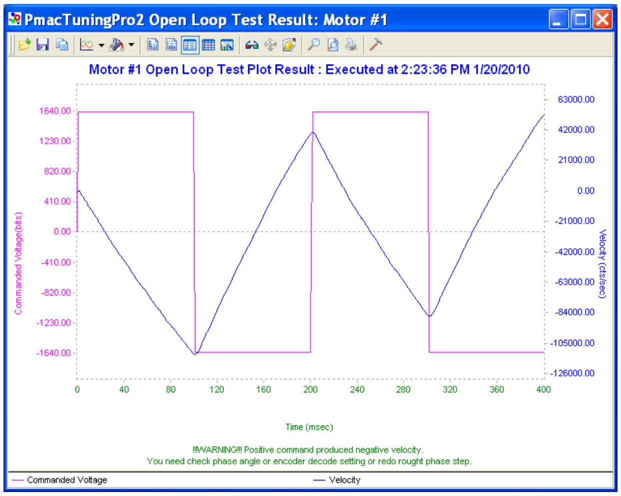
A positive command should create a velocity and position counting in the positive direction; a negative command should create a velocity and position counting in the negative direction. The open-loop test can be done manually from the terminal window (e.g. #1O5) while gathering position, velocity data, or by simply monitoring the direction of the velocity in the position window. The PMACTuningPro2 Software provides an automatic open loop utility, which is convenient to use.

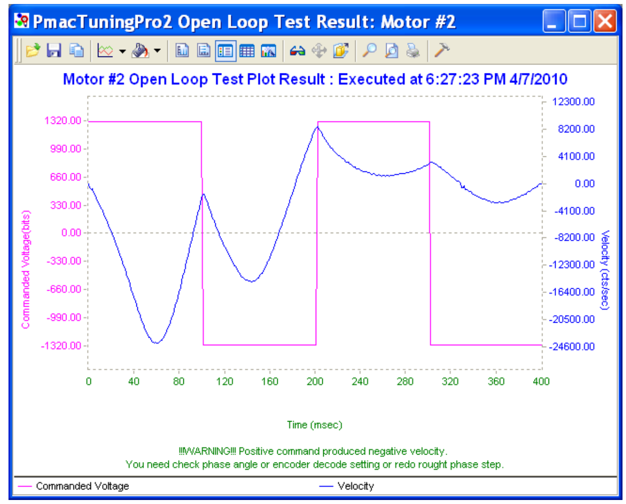
A successful open-loop test should look like the following:



The open loop magnitude (output) is adjustable, start off with 1 - 2 percent command output and increment gradually until you see a satisfactory result.

A failed open-loop test would either move the motor in the opposite direction of the command or lock it onto a phase, one the following plots may apply:





General recommendation for troubleshooting unsuccessful open loop tests:

1. Re-phase motor and try again

2. An inverted saw tooth response, most times, indicate that the direction sense of the encoder is opposite to that of the command output.

- With Quadrature | Sinusoidal | HiperFace encoders:
  Change I7mn0 to 3 from 7 (default) or vice-versa.
  Make sure Ixx70 and Ixx71 are correct.
  HiperFace sends absolute encoder data on power-up. If the on-going position direction is reversed, one needs to make sure that the absolute data sent on power-up agrees with the new direction of the encoder.

- With Resolvers:
  Change the direction from clock wise to counter clock wise in the first encoder conversion table entry (see resolver feedback setup section).

- With Absolute Serial Encoders (EnDat, SSI, BiSS, Yaskawa):
  The Geo Brick Drive has no control on the direction sense of the serial data stream. There are no software parameters that allow this change. Normally, the direction sense is set by jumpers or software at the encoder side. In this scenario, the commutation direction has to be reversed to match the encoder sense. This is usually done by swapping any two of the motor leads and re-phasing.

3. If the motor locks in position (with an open loop command i.e.#nO5) like a stepper motor, then the phasing has failed, and most times this indicates that the commutation cycle size is setup wrong (check Ixx70, Ixx71). Also it could indicate that the encoder sense is reversed.

Note

Halls Phasing (where applicable) needs to be re-configured if the motor direction is reversed.

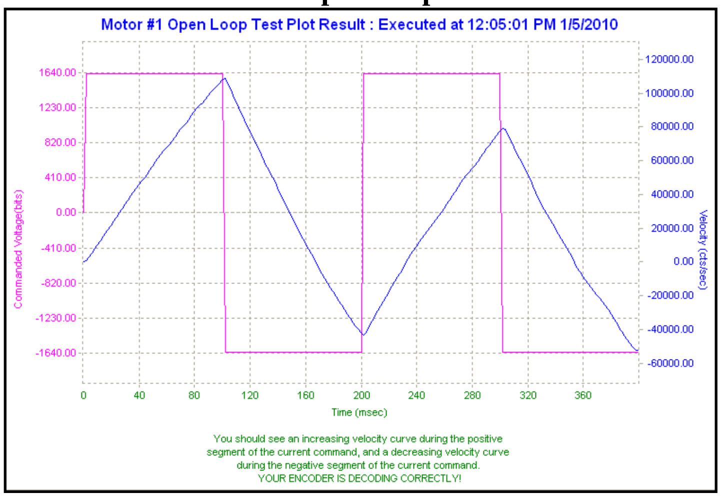
Position-Loop PID Tuning: Ixx30…Ixx39

The position-loop tuning is done as in any Turbo PMAC PID-Loop setup. The PMACTuningPro2 automatic or interactive utility can be used for fine tuning.

WARNING

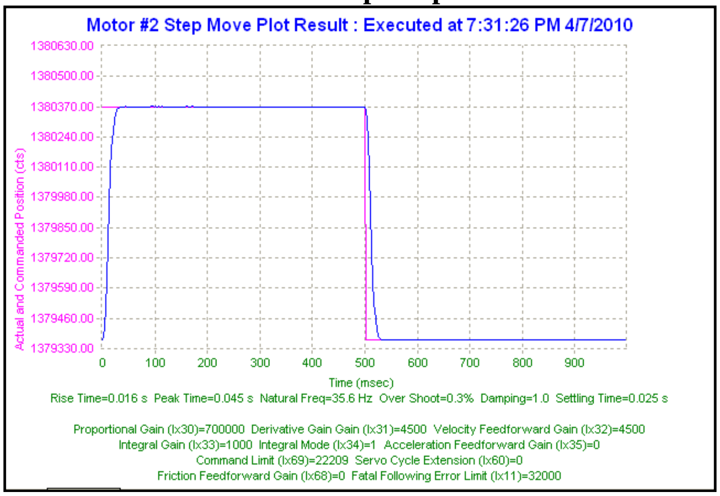
Remember to perform an Open Loop Test after phasing and before trying to close the loop on the motor to make sure that the encoder decode (I7mn0) is correct. A positive open loop command should result in positive direction (of the encoder) motion and vice-versa.

Good Open Loop Test

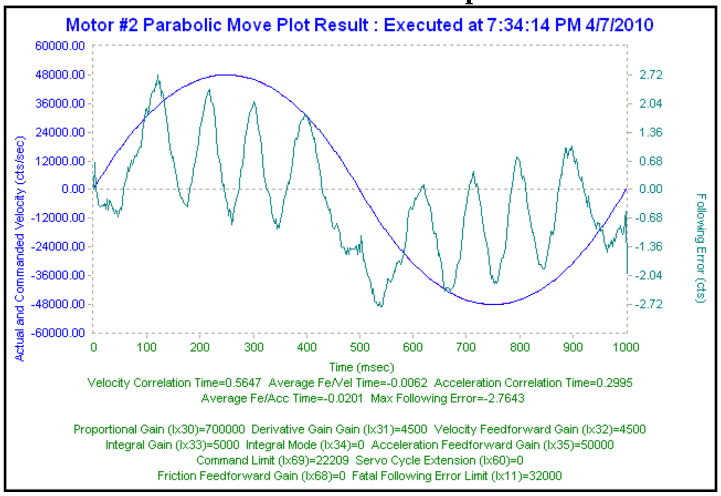


Acceptable Step and Parabolic position responses should look like the following:

Position Step Response



Position Parabolic Response



High Speed Motors

With Geo Brick Drives, motors conceived to operate at higher speeds (e.g. greater than 15,000 rpm) require the implementation of commutation delay compensation Ixx56. This is also known as phase advance. It only applies to motors commutated (synchronous or asynchronous) by PMAC.

Ixx56 permits the PMAC to compensate lags in the electrical circuits of the motor phases, and/or for calculation delays in the commutation, therefore improving high-velocity performance.

The commutation delay compensation Ixx56 is best set up experimentally by running the motor at high speeds, monitoring the current draw (e.g. using the current calculation PLC) and finding the setting which minimizes the current draw of the motor without causing it to lose phase (typically triggering a fatal following error or over current fault on the drive).

Example:
A DC brushless motor with a 2048 cts/rev encoder is desired to have a phase advance of 5 “electrical” degrees at a speed of 30,000 rpm. The system is setup at a 4.5 KHz servo clock. The following equation can be used to compute an empirical or a starting value for Ixx56:

```
#define ServoCycle     4500    ; Servo Clock [HZ]
#define Mtr4DesSpeed   30000   ; Max desired speed [rpm]
#define Mtr4EncSF      2048    ; Motor #4 Scale Factor [cts/rev]
#define Mtr4PhaAdv     5       ; Motor #4 Phase Advance Angle [electrical deg.]

I456=Mtr4PhaAdv*2048*60*ServoCycle/(360*Mtr4DesSpeed*Mtr4EncSF*96*32)
```

Note

This parameter is especially useful with motors commutated over a Macro ring.

AC Induction (Asynchronous) Motor Setup – With Encoder

Before you start

- This section assumes that the encoder has been wired and configured correctly in the Encoder Feedback section. And that moving the motor/encoder shaft by hand shows encoder counts in the position window.
- The AC Induction Motor Setup section is conceived for Motor#4, which is most commonly used in Geo Brick Drive applications as a Spindle.
- Parameters with Comments ending with **-User Input** require the user to enter information pertaining to their system/hardware.
- Description of the setup parameters can be found in the Turbo Software Reference Manual

Caution

Using an external shunt resistor is highly advised with spindle applications due to the excessive energy transmitted back into the Geo Brick Drive during decelerations.

For simplicity and better presentation of the parameters to be set up, we will consider the following example: A 4-axis Geo Brick Drive 8/16A, powered with 208VAC three-phase is driving a 230VAC spindle on channel 4:

```
#define Mtr4Speed            1760   ; Motor Rated Speed w/o field weakening [rpm] -User Input
#define LineFrequency        60     ; Line frequency for rated speed [Hz]         -User Input
#define Mtr4NoLoadCur        6.8    ; Rated current at no load [A]                -User Input
#define Mtr4Voltage          230    ; Motor rated voltage [VAC]                   -User Input
#define Mtr4TimeCst          0.75   ; Motor time constant (optional) [sec]        -User Input
#define Mtr4Poles            4      ; Motor number of poles                       -User Input

#define ACBusVoltage         208    ; Three-phase 208 VAC Bus Voltage             -User Input
```

Commutation Angle, Current Mask: Ixx72, Ixx84

```
I472=1365      ; Motors #4 Commutation phase angle (Geo Brick Drive specific)
I484=$FFF000   ; Motors #4 Current-Loop Feedback Mask Word (Geo Brick Drive specific)
```

PWM Scale Factor: Ixx66

If Motor Rated Voltage > Bus Voltage:

```
I466=1.10*I7000                       ; Motor #4 PWM Scale Factor. Set to 10% above PWM Count.
```

If Bus Voltage > Motor Rated Voltage:

A Geo Brick Drive connected to 3-Phase 230 VAC Bus, driving a 110 VAC Induction Motor. In this case, Ixx66 serves as a voltage limit for the motor

```
I466=1.10*I7000*Mtr4Voltage/ACBusVoltage     ; Motor #4 PWM Scale Factor
```

Current Feedback Address: Ixx82

```
I482=$07801E   ; Motor 4 Current Feedback Address
```

Commutation Position Address, Commutation Enable: Ixx83, Ixx01

Digital Quadrature Feedback (Default)

```
I483=$078019   ; Motor #4 On-going Commutation Position Address
I401=1         ; Motor #4 Commutation Enabled, from X-register
```

Note

AC Induction Motors are not generally used for (high precision) positioning; it is assumed that a quadrature feedback type device is being used. For setting up other feedback devices, the commutation position address (Ixx83) would have to change. Contact Technical Support for help with these special cases.

Magnetization Current, Slip Gain: Ixx77

The quadrature current is much smaller than the direct current with AC induction motors therefore the magnetization current, Ixx77, can be estimated using the no load current at a specified voltage:

```
#define Ch4MaxADC      26.02   ; =26.02 for 8/16A, see electrical specs of the drive -User Input
#define Ch4MaxOutput   P7004   ; Channel 4 Maximum Command Output
#define Mtr4EstMagCur  P7005   ; Motor #4 Estimated Magnetization current [16-bit DAC]

Ch4MaxOutput=32767*SQRT(3)/2
Mtr4EstMagCur= Mtr4NoLoadCur*ACBusVoltage/Mtr4Voltage
I477=Mtr4EstMagCur*Ch4MaxOutput*SQRT(2)/Ch4MaxADC    ; Initial Guess
```

Motor Slip Gain: Ixx78

Ixx78 controls the relationship between the torque command and the slip frequency of the magnetic field on the rotor of an AC Induction (Asynchronous) motor. While it is usually set experimentally, The Motor Slip Gain Ixx78 can be calculated from either the motor name plate, or the rotor time constant.

Calculating Slip Gain From Name Plate Data:

```
#define We             P7006   ; Electrical Frequency, in Radians/Sec
#define Wm             P7007   ; Rated mechanical pole frequency, in radians/sec
#define Tp             P7008   ; Phase Clock, in Seconds
#define PI             3.1416  ; PI Constant

Tp=1/(PhaseClk*1000)                 ; PhaseClk is defined in clock calculation section
We=LineFrequency*2*PI                ;
Wm=(Mtr4Speed*2*PI*Mtr4Poles)/(60*2) ;
I478=(We-Wm)*Tp*I477/32768           ; Motor #4 Slip Gain Constant
```

Note

Using the name plate information to calculate the slip gain requires an initial estimation of the magnetization current Ixx77. If the magnetization current is changed, as explained in a subsequent step, the slip gain needs to be adjusted accordingly.

Calculating Slip Gain From Rotor Time Constant. Example:

```
#define Tp      P7008   ; Phase Clock, in Seconds

Tp =1/(PhaseClk*1000) ; PhaseClk is defined in clock calculation section
I478= Tp/Mtr4TimeCst  ; Motor #4 Slip Gain Constant
```

I2T Protection: Ixx57, Ixx58, Ixx69

The lower values (tighter specifications) of the Continuous/Instantaneous current ratings between the Geo Brick Drive and motor are chosen to setup I2T protection.

If the peak current limit chosen is that of the Geo Brick Drive (possible values 10, 16, or 30 Amps) then the time allowed at peak current is set to 2 seconds.

If the peak current limit chosen is that of the Motor, check the motor specifications for time allowed at peak current.

Examples:

- For setting up I2T on a 5/10-Amp Geo Brick Drive driving a 3/9-Amp motor, 3 amps continuous and 9 amps instantaneous will be used as current limits. And time allowed at peak is that of the motor.
- For setting up I2T on a 5/10-Amp Geo Brick Drive driving an 8/16-Amp motor, 5 amps continuous and 10 amps instantaneous will be used as current limits. And time allowed at peak is 2 seconds.
- For setting up I2T on a 15/30-Amp channel on a Geo Brick Drive driving a 12/45-Amp motor, 12 amps continuous and 30 amps instantaneous will be used as current limits. And Time allowed at peak is 2 seconds.

A 4-axis 8/16 Amp Geo Brick Drive, is driving a 7/20 Amp AC Induction Motor on channel 4.
The continuous current limit is 7. The instantaneous current limit is 16.

```
I15=0                                ; Trig Operations in Degrees
;#define ServoClk              P7003  ; ServoClk is defined in clock calculation section [KHz]
#define Mtr4ContCurrent        7      ; Motor #4 Continuous Current Limit [Amps] -User Input
#define Mtr4PeakCurrent        16     ; Motor #4 Instantaneous Current Limit [Amps] -User Input
#define I2TOnTime              2      ; Time allowed at peak Current [sec] -User Input

I457=INT(32767*(Mtr4ContCurrent*1.414/Ch4MaxADC)*cos(30))
I469=INT(32767*(Mtr4PeakCurrent*1.414/Ch4MaxADC)*cos(30))
I458=INT((I469*I469-I457*I457+I477*I477)*ServoClk*1000*I2TOnTime/(32767*32767))
```

Note

This (software) I2T protection is computed by PMAC to protect the motor (results are estimated RMS values).
The Geo Brick Drive has its own built-in hardware I2T as an additional layer of safety and drive protection.

Note

I2T has to be corrected to reflect the finalized magnetization current Ixx77. This is done at a subsequent step in the AC Induction Motor Setup.

Commutation Cycle Size: Ixx70, Ixx71

The ratio of Ixx70/Ixx71 represents the number of encoder counts per electrical cycle. For an AC Induction Motor, we will limit the explanation for digital quadrature feedback devices since they are the most widely used for this type of motor.

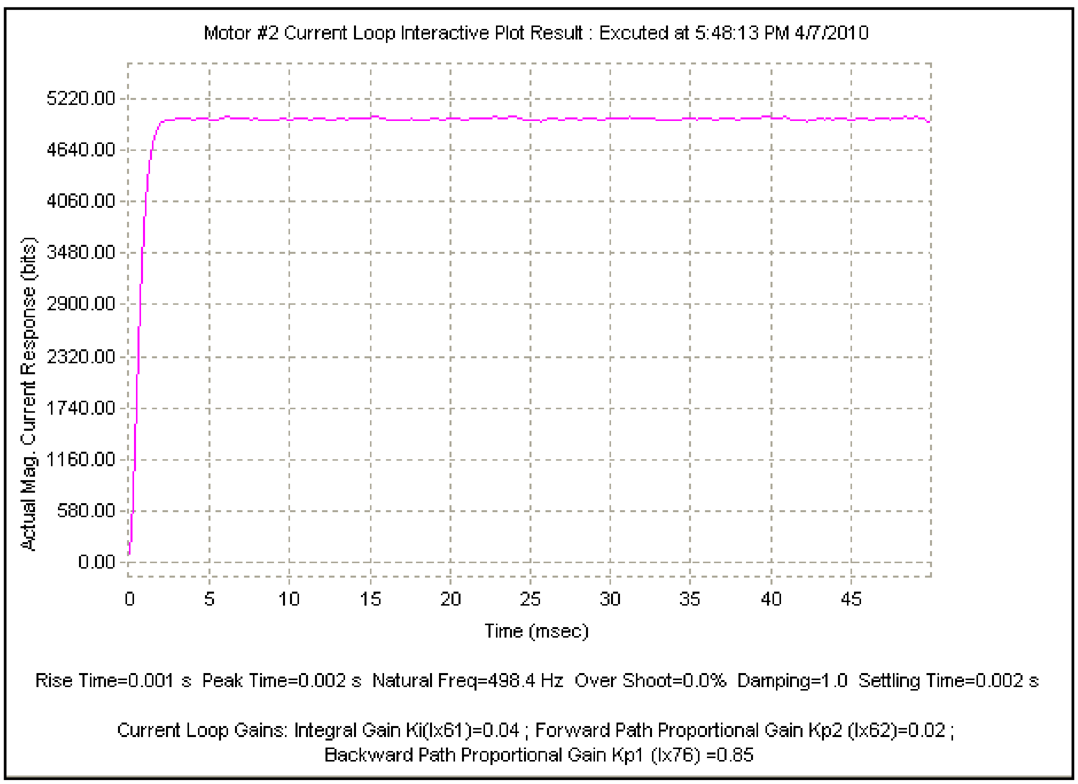
Digital Quadrature Feedback
Ixx70= {Number of pole pairs of the motor} **–User Input**
Ixx71= {Number of counts per revolution} **–User Input**

ADC Offsets: Ixx29, Ixx79

The ADC offsets importance may vary from one system to another, depending on the motor(s) type and application requirements. They can be left at default of zero especially if a motor setup is to be reproduced on multiple machines by copying the configuration file of the first time integration. However, they should ultimately be set to minimize measurement offsets from the A and B-phase current feedback circuits, respectively (read in Suggested M-variables Mxx05, Mxx06).

Current-Loop Tuning: Ixx61, Ixx62, Ixx76

The current-loop tuning is done as in any Turbo PMAC digital current loop setup. The PMACTuningPro2 automatic or interactive utility can be used to fine-tune the Current-Loop. An acceptable Current-Loop step response would look like:



Note

Current-Loop Natural Frequencies in the range of 200-500 Hz are good enough for most applications. Tuning the current loop too tightly (Natural Frequency > 800Hz) can have deteriorating effects on the position loop tuning.

Open-Loop Test, Encoder Decode: I7mn0

Having calculated the Slip Gain Ixx78 and performed a satisfactory current-loop tuning, an open-loop test can now be performed to verify the direction sense of the encoder counting versus the command output. A positive command should create a positive velocity and a position counting in the positive direction; a negative command should create a negative velocity and a position counting in the negative direction.

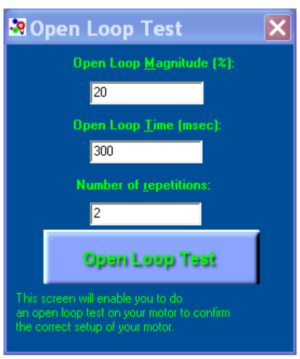
Because of the slow acceleration nature of AC Induction motors, a manual open loop test might be more practical than the automatic utility from the PMACTuningPro2 Software.

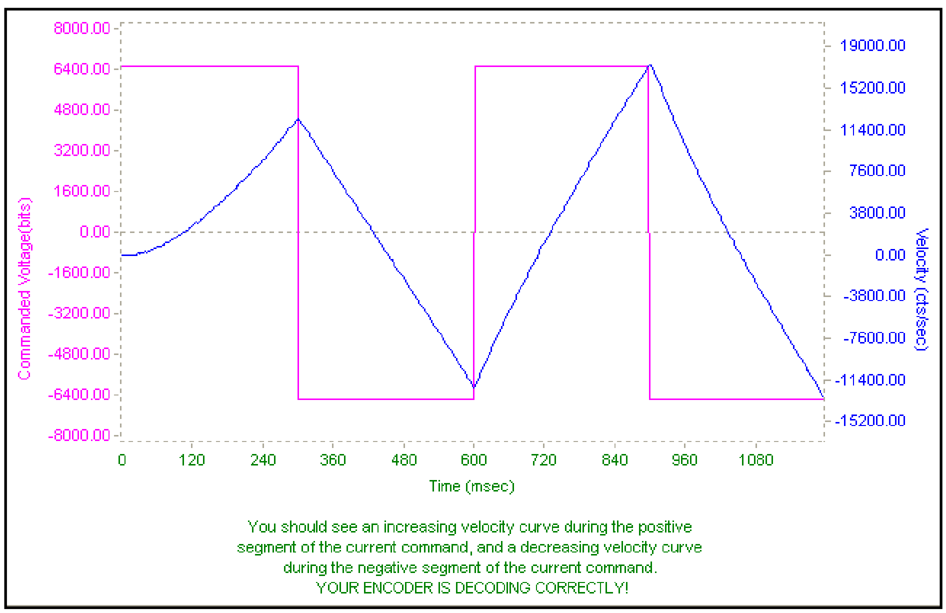
Manual Open-Loop Test: Issue a conservative open loop command from a terminal window (i.e. #4o10) and monitor the velocity in the position window. The motor should rotate in the positive direction. Similarly a negative open-loop command (#4o-10) should move the motor in the negative direction. If no or very little motion is observed, increase the magnitude by increments of 10 (i.e. #4o20, #4o-20) to obtain a conclusive result.

Automatic Open-Loop Test: In order to obtain good results using the automatic utility with AC induction motors, the test magnitude and time are set to values which are larger than usual. This is due to the slow rise time with most AC Induction Motors.

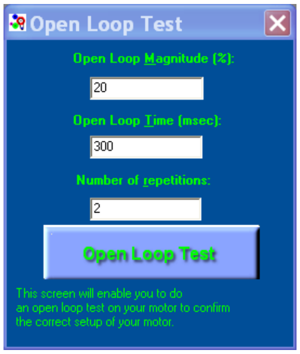
Examples:

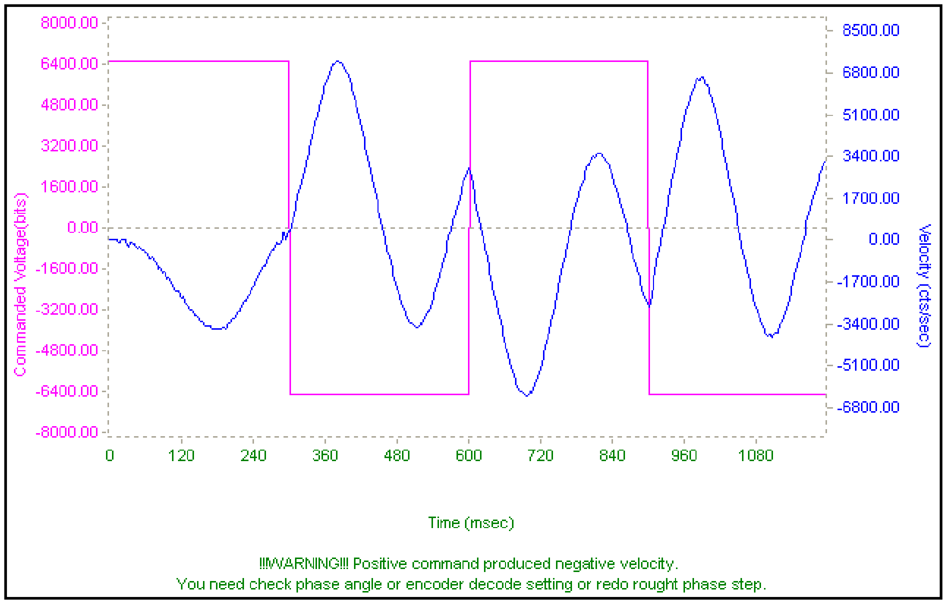
Automatic Open-loop test magnitude of 20% with a test time of 300 msec showing good response and correct encoder decode I7mn0 (I7040 for motor #4)





Automatic Open-loop test, 20% magnitude and 300 milliseconds move time, showing incorrect encoder decode. AC Induction Motors, with incorrect encoder decode, generally show erratic data in the Open-Loop test (as opposed to a nice inverted saw-tooth shape curve with DC Brushless motors). In either cases, I7mn0 for motor #4 (i.e. I7040) needs to be changed from 3 to 7 or vice-versa.





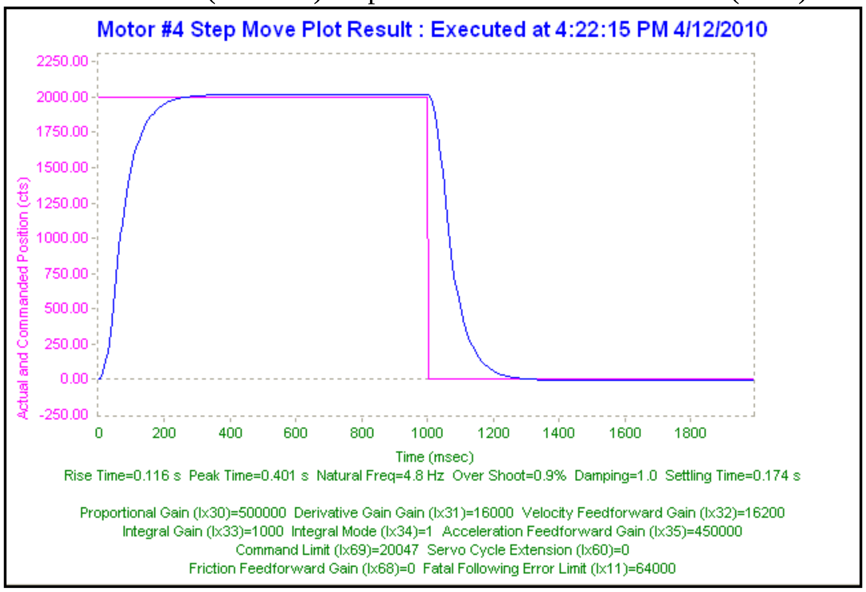
Note

Wrong commutation cycle size can lead to erratic Open-Loop test results or no motor movement. Double check Ixx70, and Ixx71 for proper values.

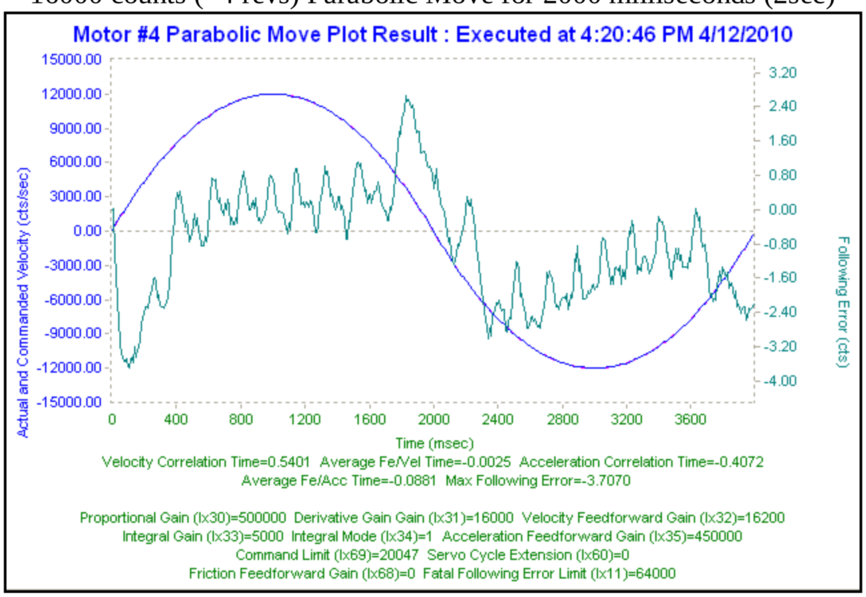
Position-Loop PID Tuning: Ixx30…Ixx39

The position-loop tuning is done as in any Turbo PMAC PID-Loop setup. The PMACTuningPro2 automatic or interactive utility can be used for tuning.

2000 counts (~1/2 rev) Step Move for 1000 milliseconds (1 sec)



16000 counts (~4 revs) Parabolic Move for 2000 milliseconds (2sec)



Note

Due to the slow response nature of AC Induction Motors, allow relatively longer move times.
Fine/Tight tuning is normally not critical with AC Induction, especially if you decide to run in open-loop mode (see next section).

Optimizing Magnetization Current Ixx77, Slip Gain Ixx78

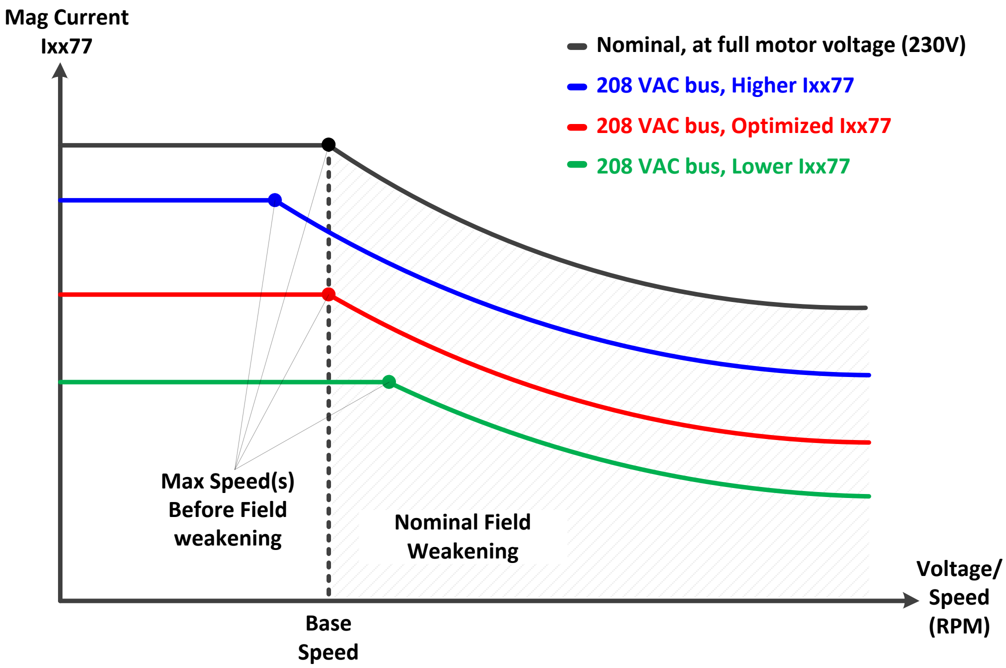
Magnetization current

During the optimization procedure, the motor will rotate up to its maximum velocity. Make sure that the motor is well mounted/clamped and uncoupled from any rotating inertia.

Always be ready to issue a Kill if the motor exceeds its maximum specified speed.

With AC Induction motors, the magnetization current Ixx77 is used to provide a stator current component parallel to the estimated rotor magnetic field (the "direct" current -- the control loop then determines the magnitude of the "quadrature" current perpendicular to this component).

In open loop mode, and given a fixed magnetization current Ixx77, the induction motor will accelerate at the slip gain rate Ixx78 and reach a certain base speed. This, theoretically, is the motor name plate speed. It usually specifies the maximum motor speed before applying field weakening.
Field weakening consists of lowering the magnetization current in order to achieve speeds superior to the motor base speed (name plate). The lower the magnetization current, the higher is the speed that can be achieved.



Ixx77 Optimization Procedure:

- Issue a 25% Open Loop Command (i.e. #4O25) and monitor the motor velocity in the position window (scaled to rpm). The motor should reach and run steadily at a speed that is less than or equal to the motor base speed. The goal of this first step is to achieve a smooth run at a constant speed.

Caution

If the motor reaches a speed that is greater than the rated base speed, Kill the motor, increase Ixx77 and redo the open-loop test again.

Note

If the motor takes too long to take off, or does not move, increase the open loop command by increments of 10.

- If the motor has reached its base speed in the first step, then this is the nominal magnetization current Ixx77. Skip the rest of this procedure.

- Most likely, that the motor will reach a speed that is much lower than the base speed. Decrease Ixx77 gradually (decrements of 500) and wait for the velocity to settle. The desired nominal Ixx77 is the value allowing the motor to reach its base speed.

- Kill the motor

Slip Gain

With AC induction motor, the slip gain Ixx78 controls the relationship between the torque command and the slip frequency of magnetic field on the rotor. It is directly proportional to the torque

Having optimized the magnetization current Ixx77, a slip gain Ixx78 correction is a good starting point. This can be done using the empirical equation and substituting the initially guessed magnetization gain with the optimized value:

```
I478=(We-Wm)*Tp*I477/32768     ; Motor #4 Slip Gain Constant
```

Note

At this point of the AC Induction Motor Setup, you should be able to run the motor in either Open-Loop (i.e. #nO25) at base speed or closed-Loop (i.e. Jog commands) at a pre-defined speed and acceleration (Ixx22, Ixx19)

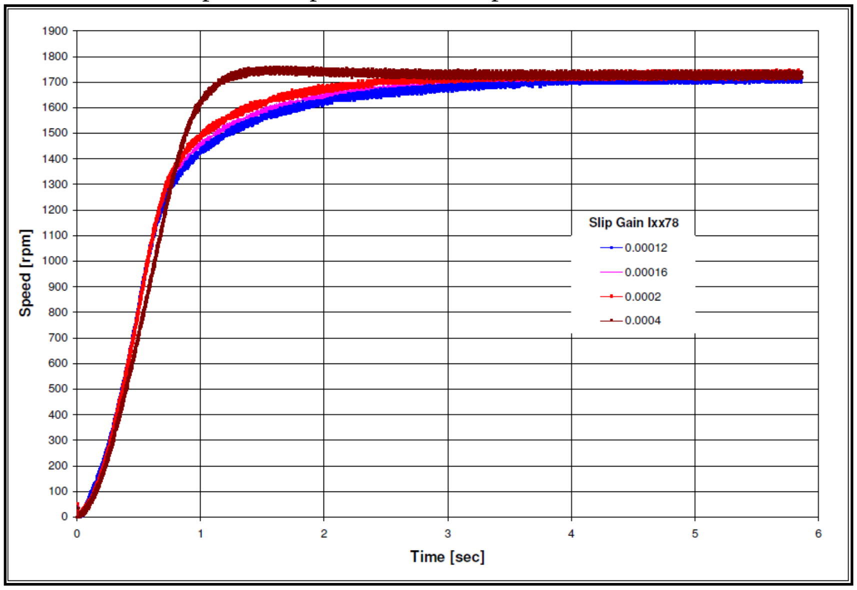
If you are satisfied with the rise time of the motor or if it is not of significance for the application then the slip gain optimization procedure can be skipped.

If, in closed-loop, you trigger a fatal following error, try increasing the following error limit or decreasing the acceleration rate (Ixx19) which could be violating how quick the slip gain Ixx78 allows the motor to accelerate.

Optimization procedure (optional):

- Gather velocity versus time data while issuing an open loop command (i.e. #4O25)
- Increase the slip gain gradually (small increments~0.00001) until you reach a satisfactory rise time. Of course, the time constant of the motor should not be violated.

Slip Gain Optimization, Experimental Data:



Note

High slip gain values can cause the motor to hunt and lose smoothness.

Correcting I2T Settings

The motor continuous current limit has to be corrected for the optimized Ixx77

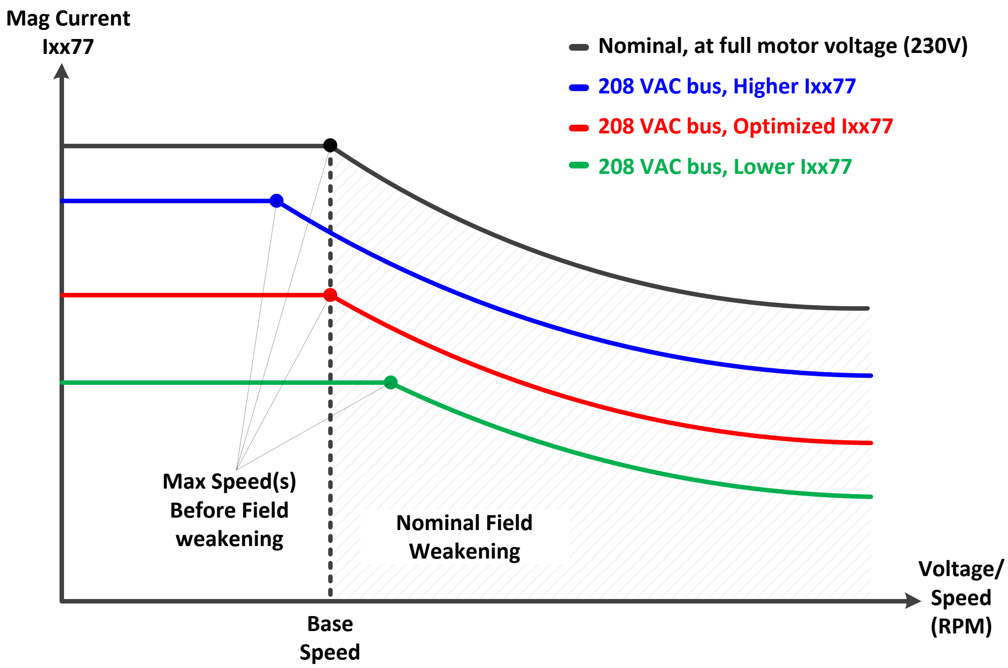
```
I458=INT((I469*I469-I457*I457+I477*I477)*ServoClk*1000*I2TOnTime/(32767*32767))
```

Closed-Loop vs. Open-Loop Operation

AC induction motors with encoder can be commanded to run in either open-loop mode (i.e. #nO25) at a pre-defined base speed or closed-loop mode at various programmable speeds (e.g. rigid tapping).

Field Weakening

Field weakening consists of decreasing the stator current component (lowering the magnetization current Ixx77) in order to allow AC induction motors to achieve speeds superior to the specified base speed (name plate). The lower the magnetization current, the higher is the speed that can be achieved.



Field weakening can be set up experimentally with the goal of finding the “lowest” minimum value of Ixx77 which allows the motor to run at the user’s desired top speed, without exceeding the maximum motor specified speed (i.e. bearings, overheating limitations).

The magnetization current Ixx77 can then be adjusted on the fly depending on the commanded speed, rpm range scheduling in a background PLC for example, to provide good torque for positioning (e.g. rigid tapping) at lower speeds, and allow high speed operation (e.g. for cutting) at the same time. In most cases, the slip gain Ixx78 need not be changed.

High Speed Spindles

With Geo Brick Drives, spindles conceived to operate at higher speeds (e.g. greater than 15,000 rpm) require the implementation of commutation delay compensation Ixx56. This is also known as phase advance. It only applies to motors commutated by PMAC.

Ixx56 permits the PMAC to compensate lags in the electrical circuits of the motor phases, and/or for calculation delays in the commutation, therefore improving high-velocity performance.

The commutation delay compensation Ixx56 is best set experimentally by running the motor at high speeds, monitoring the current draw (e.g. using the current calculation PLC) and finding the setting that minimizes the current draw of the motor without causing it go get out of phase (typically triggering a fatal following error or over current fault on the drive).

Example:
An AC induction motor with a 2048 cts/rev encoder is desired to have a phase advance of 5 “electrical” degrees at a speed of 30,000 rpm. The system is setup at a 4.5 KHz servo clock. The following equation can be used to compute an empirical value for Ixx56:

```
#define ServoCycle     4500    ; Servo Clock [HZ]
#define Mtr4DesSpeed   30000   ; Max desired speed [rpm]
#define Mtr4EncSF      2048    ; Motor #4 Scale Factor [cts/rev]
#define Mtr4PhaAdv     5       ; Motor #4 Phase Advance Angle [electrical deg.]

I456=Mtr4PhaAdv*2048*60*ServoCycle/(360*Mtr4DesSpeed*Mtr4EncSF*96*32)
```

Note

This parameter is especially useful with motors commutated over a Macro ring.

AC Induction (Asynchronous) Motor Setup – Without Encoder, Direct Micro-Stepping

Before you start

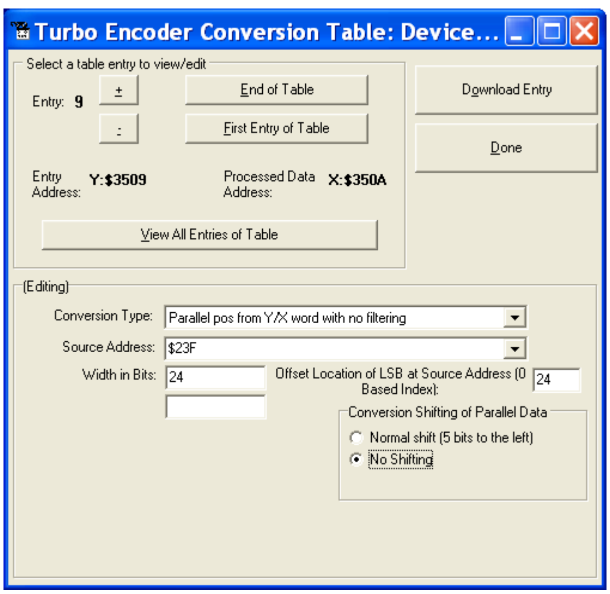
- The AC Induction Motor Setup section is conceived for Motor#4, which is most commonly used in Geo Brick Drive applications as a Spindle.
- Parameters with comments ending with **-User Input** require the user to enter information pertaining to their system/hardware.
- Description of the setup parameters can be found in the Turbo Software Reference Manual

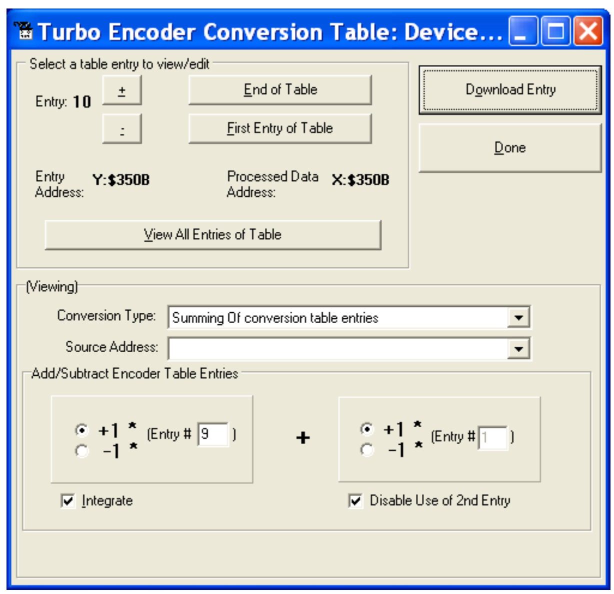
For an AC Induction Motor with no encoder, we will use the direct microstepping technique for direct PWM motor control. This technique creates a simulated position sensor and feedback loop by numerically integrating the (velocity) command output from the servo loop. This integration requires two entries in the encoder conversion table. The resulting simulated position value can be used for both motor phase commutation and servo-loop feedback.

Encoder Conversion Table Setup

The first entry in the encoder conversion table (ECT) for each Induction Motor must read the servo-loop output like an absolute encoder. This is done with a "parallel-read" entry of a Y/X double register (the data is in X), unshifted and unfiltered; specifying the use of 24 bits of the 48-bit Y/X register, starting 24 bits from the low end. This is effectively like reading a 24-bit DAC register.

The second entry in the ECT for each Ac Induction motor integrates the result of the first entry.





1- Find an open ECT, or preferably go to the end of Table.

2- Choose Conversion Type, Width in Bits and Offset Location (as shown)

3- Choose No Shifting, then enter the source address corresponding to the channel/motor # (see table below)

4- Click Download Entry

1- Go to the Next Entry

2- Choose Conversion Type, enter previous entry number, delete the source address and disable the use of second entry (as shown)

3- Click Download entry, and record the processed data address (i.e. X:$350B). This is where the commutation and position simulated encoder data is generated.

Motor Quadrature/Torque Command Value Registers

Motor #	Address (X-Memory)	Motor #	Address (X-Memory)
1	$0000BF	5	$0002BF
2	$00013F	6	$00033F
3	$0001BF	7	$0003BF
4	$00023F	8	$00043F

Motor Activation, Position, Velocity Pointers: Ixx03, Ixx04

The position and velocity pointers (no external encoder used) will be set to the integration result:

```
I400=1                         ; Motor #4 Active
I403=$350B     I404=$350B      ; Motor #4 position and velocity feedback Address
```

Commutation Angle, Current Mask, Flag Mode Control: Ixx72, Ixx84, Ixx24

```
I472=1365      ; Motors #4 Commutation phase angle (Geo Brick Drive specific)
I484=$FFF000   ; Motors #4 Current-Loop Feedback Mask Word (Geo Brick Drive specific)
I424=$000401   ; Disable 3rd harmonic, enable over-travel limits
```

PWM Scale Factor: Ixx66

If Motor Rated Voltage > Bus Voltage:

```
I466=1.10*I7000        ; Motor #4 PWM Scale Factor. Set to 10% above PWM Count.
```

If Bus Voltage > Motor Rated Voltage:

A Geo Brick Drive connected to 3-Phase 230 VAC Bus, driving a 110 VAC Induction Motor. In this case, Ixx66 serves as a voltage limit for the motor

```
#define BusInput       230             ; Bus Voltage, 230 VAC -User Input
#define Mtr4Voltage    110             ; Motor #4 Rated Voltage, 110 VAC Motor -User Input

I466=1.10*I7000*Mtr4Voltage/BusInput  ; Motor #4 PWM Scale Factor
```

Current Feedback Address: Ixx82

```
I482=$07801E   ; Motor 4 Current Feedback Address
```

Commutation Position Address, Commutation Enable: Ixx83, Ixx01

```
I483=$350B     ; Motor #4 On-Going Commutation Position Address (from Integration Result)
I401=1         ; Motor #4 Commutation Enabled, from X-register
```

Commutation Cycle size: Ixx70, Ixx71

```
I470=1         ; Direct-Microstepping technique specific
I471=65536     ; Direct-Microstepping technique specific
```

Maximum Achievable Motor Speed, Output Command Limit: Ixx69

In Micro-Stepping, the maximum achievable speed is proportional to the Servo clock and electrical cycle length. A faster Servo Clock results in higher achievable motor speeds.

The smaller value of the Theoretical versus Calculated output command limit Ixx69 is chosen.

Theoretical Ixx69

Sine Table: 2048
Electrical Length = 2048*32 (5-bit shift) = 65536
Max Electrical Length/Servo Cycle = Electrical Length/6 = 10922.66667 (6 cycles to ensure good commutation)
Max Electrical Length per Servo Cycle/256 = Micro-Stepping Theoretical Ixx69 = 42.6667

Calculated Ixx69

Maximum-Achievable Motor Speed (RPM) =
(Servo Clock*1000) / (Electrical Cycles per Revolution*6)*60
Calculated Ixx69 =
Max Motor Speed* Electrical Cycles per Revolution/ 60 * 256/(Servo Clock *1000)

```
#define Mtr4Speed             1760    ; Motor #4 Base Speed Spec [RPM] -User Input
#define ElecCyclePerRev       2       ; No of pole pairs = # of Elec Cycles -User Input

;#define ServoClk             P7003   ; [KHz] Computed in Dominant Clock Settings Section
#define MaxMtr4Speed          P7004   ; Motor #4 maximum "commanded" achievable motor speed
#define CalculatedIxx69       P7005   ; Calculated Ixx69

MaxMtr4Speed=(ServoClk*1000)/(ElecCyclePerRev*6)*60
CalculatedIxx69=Mtr4Speed*ElecCyclePerRev/60*256/(ServoClk*1000)
```

If Calculated Ixx69>Theoretical Ixx69 => I469= Theoretical Ixx69
If Calculated Ixx69<Theoretical Ixx69 => I469= Calculated Ixx69

```
I469=CalculatedIxx69                  ;
```

Note

The maximum "commanded" speed is governed by the Servo Period. It has to be increased if a greater maximum "commanded" speed is desired.

Note

If the desired speed requires very high servo clock rate, then the servo cycle extension Ixx60 can then be used to scale back the servo sampling for what the existing motors have been tuned about.

I2T Protection, Magnetization Current: Ixx57, Ixx58, Ixx69, Ixx77

The lower values (tighter specifications) of the Continuous/Instantaneous current ratings between the Geo Brick Drive and motor are chosen to setup I2T protection.

If the peak current limit chosen is that of the Geo Brick Drive (possible values 10, 16, or 30 Amps) then the time allowed at peak current is set to 2 seconds.

If the peak current limit chosen is that of the Motor, check the motor specifications for time allowed at peak current.

Examples:

- For setting up I2T on a 5/10-Amp Geo Brick Drive driving a 3/9-Amp motor, 3 amps continuous and 9 amps instantaneous will be used as current limits. And time allowed at peak is that of the motor.
- For setting up I2T on a 5/10-Amp Geo Brick Drive driving an 8/16-Amp motor, 5 amps continuous and 10 amps instantaneous will be used as current limits. And time allowed at peak is 2 seconds.
- For setting up I2T on a 15/30-Amp channel on a Geo Brick Drive driving a 12/45-Amp motor, 12 amps continuous and 30 amps instantaneous will be used as current limits. And Time allowed at peak is 2 seconds.

A 4-axis 8/16 Amp Geo Brick Drive, is driving a 7/20 Amp AC Induction Motor on channel 4.
The continuous current limit is 7. The instantaneous current limit is 16.

```
#define Mtr4ContCurrent       7      ; Motor #4 Continuous Current Limit [Amps] -USER INPUT
#define Mtr4PeakCurrent       16     ; Motor #4 Instantaneous Current Limit [Amps] -USER INPUT
#define Ch4MaxADC             26.02  ; =16.26 for 5/10A    -USER INPUT, see electrical specs
                                     ; =26.02 for 8/16A    -USER INPUT, see electrical specs
                                     ; =48.08 for 15/30A   -USER INPUT, see electrical specs
#define I2TOnTime             2      ; Time allowed at peak Current [sec] -USER INPUT
;#define ServoClk             P7003  ; [KHz] Computed in Dominant Clock Settings Section
#define Mtr4OutLimit          P7006  ; This is Ixx69, normally used in direct digital PWM

I457=INT(32767*( Mtr4ContCurrent*1.414/Ch4MaxADC)*cos(30))
Mtr4OutLimit=INT(32767*(Mtr4PeakCurrent*1.414/Ch4MaxADC)*cos(30))
I458=INT((Mtr4OutLimit*Mtr4OutLimit-I457*I457+I477*I477)*ServoClk*1000*I2TOnTime/(32767*32767))
```

Note

I2T settings should be corrected to reflect the (optimized) magnetization current Ixx77, discussed in a subsequent section.

Magnetization Current: Ixx77

With Direct Micro-Stepping of PWM motor control, the magnetization current is set to the continuous current limit divided by square root of 2:

```
I477=I457*0.7071                     ; Ixx77=Ixx57/SQRT(2)
```

Motor Slip Gain: Ixx78

Ixx78 controls the relationship between the torque command and the slip frequency of magnetic field on the rotor of an AC Induction (Asynchronous) motor. While it is usually set experimentally, The Motor Slip Gain Ixx78 can be calculated either from Motor Name Plate, or Rotor Time Constant.

Calculating Slip Gain From Name Plate Data. Example:

A 4-pole induction motor has a rated speed of 1760 rpm at a 60 Hz electrical frequency:

```
#define LineFrequency  60      ; Electrical Line Frequency at this speed [Hertz] -USER INPUT
#define Mtr4Poles      4       ; Motor #4 Number of Poles -USER INPUT

#define We             P7007   ; Electrical Frequency, in Radians/Sec
#define Mtr4Wm         P7008   ; Motor #4 Rated mechanical pole frequency, in radians/sec
#define Tp             P7009   ; Phase Clock, in Seconds
#define PI             3.1416  ; PI Constant

Tp=1/(PhaseClk*1000)                         ; Note that PhaseClk is defined in Clock Calc.
We=LineFrequency*2*PI                        ;
Mtr4Wm=(Mtr4Speed*2*PI*Mtr4Poles)/(60*2)     ;

I478=(We-Mtr4Wm)*Tp*I477/32768               ; Motor #4 Slip Gain Constant
```

Calculating Slip Gain From Rotor Time Constant. Example:

An Induction Motor with a Rotor time constant of 0.75 seconds:

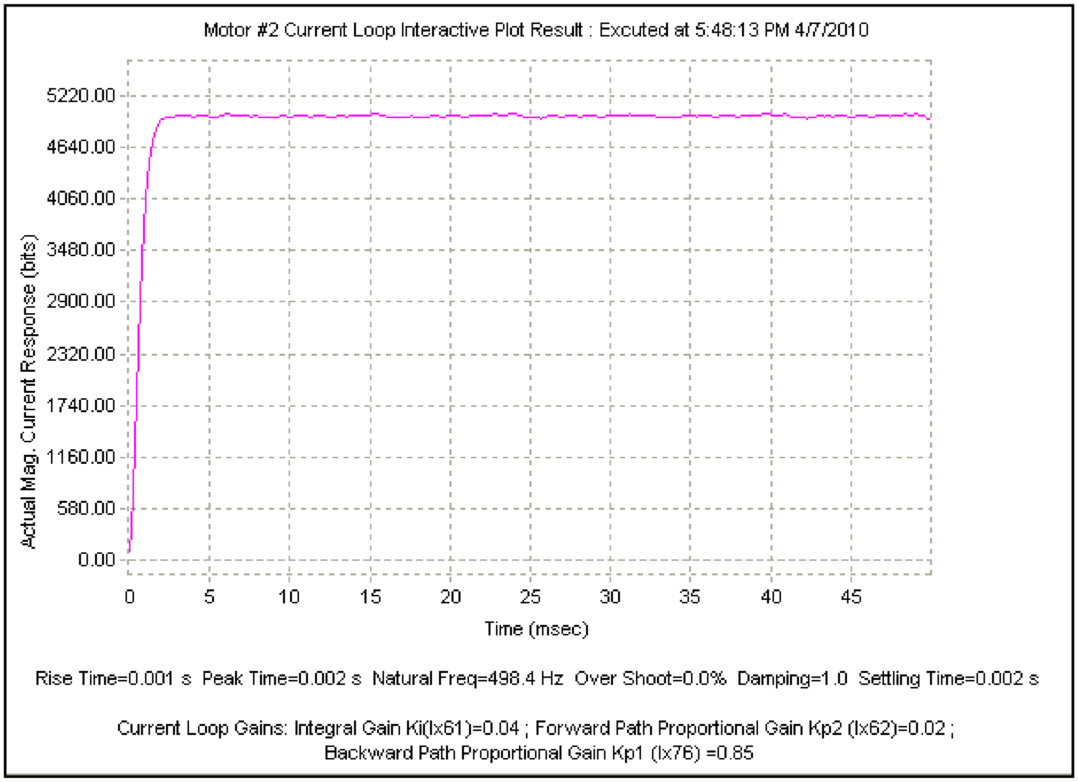
```
#define Tp             P7010   ; Phase Clock, in Seconds
#define Mtr4Tr         0.75    ; Motor #4 Rotor Time Constant, in Seconds -User Input

Tp=1/(PhaseClk*1000)           ; Note that PhaseClk was defined earlier in I2T Settings

I478=Tp/Mtr4Tr                 ; Motor #4 Slip Gain Constant
```

ADC Offsets: Ixx29, Ixx79

The ADC offsets importance may vary from one system to another, depending on the motor(s) type and application requirements. They can be left at default of zero especially if a motor setup is to be reproduced on multiple machines by copying the configuration file of the first time integration. However, they should ultimately be set to minimize measurement offsets from the A and B-phase current feedback circuits, respectively (read in Suggested M-variables Mxx05, Mxx06).

Current-Loop Tuning: Ixx61, Ixx62, Ixx76

The current-loop tuning is done as in any Turbo PMAC digital current loop setup. The PMACTuningPro2 automatic or interactive utility can be used to fine-tune the Current-Loop. An acceptable Current-Loop step response would look like:



Note

Current-Loop Natural Frequencies in the range of 200-500 Hz are good enough for most applications. Tuning the current loop too tightly (Natural Frequency > 800Hz) can have deteriorating effects on the position loop tuning.

Position-Loop PID Tuning: Ixx30…Ixx39

Since no "real" encoder is used, the position-loop PID gains are pre-calculated:

```
I430=1024 I431=0 I432=85 I433=1024 I434=1 I435..439=0
```

Moving the Motor

In Direct Micro-Stepping of AC Induction motors, the pseudo closed-loop allows the use of Jog commands for positioning, rotating at a pre-specified speed, or indefinite rotation in either direction. In this mode, the AC Induction motor is commanded exactly the same as a DC Brushless (Servo) motor.

Counts per Revolution

The number of counts per revolution is calculated as follows:

```
#define Mtr4StepAngle         P7010   ; Motor #4 Step Angle
Mtr4StepAngle =360/(ElecCyclePerRev*4)
#define Mtr4CtsPerRev         P7011   ; Motor #4 Counts Per Revolution
Mtr4CtsPerRev=360*512/ Mtr4StepAngle
```

Example: A 4-pole AC Induction motor has 2 electrical cycles per revolution, which translates into a step angle of 45 degrees, or 4096 counts per revolution.

Knowing the number of counts per revolution, the Jog maximum acceleration Ixx19 (and motion program maximum acceleration Ixx17) and Velocity Ixx22 (and motion program maximum velocity Ixx16) can be set correspondingly.

Note

Start with slow acceleration rates (i.e. default of 0.015625) to make sure top speeds are attainable, and then increase the acceleration up to permissible motor specified rates.

DC Brush Motor Setup

Before you start

- At this point of the setup process it is assumed that the encoder has been wired and configured correctly in the Encoder Feedback section. And that moving the motor/encoder shaft by hand shows encoder counts in the position window.
- Parameters with Comments ending with **-User Input** require the user to enter information pertaining to their system/hardware.
- Downloading and using the suggested M-variables is highly recommended.
- Description of the setup parameters can be found in the Turbo Software Reference Manual

Phasing Search Error Bit, Current-Loop Integrator Output (Ixx96)

On power-up, the phasing search error bit has to be cleared to allow motor move commands to DC Brush motors. The current-loop integrator output should not be allowed to build up over time. The motor (non-existent) direct current-loop output should be zero-ed periodically. This is equivalent, but more efficient than setting Ixx96 to 1.

```
M148->Y:$C0,8,1        ; Motor 1 Phasing error fault bit
M248->Y:$140,8,1       ; Motor 2 Phasing error fault bit
M348->Y:$1C0,8,1       ; Motor 3 Phasing error fault bit
M448->Y:$240,8,1       ; Motor 4 Phasing error fault bit
M548->Y:$2C0,8,1       ; Motor 5 Phasing error fault bit
M648->Y:$340,8,1       ; Motor 6 Phasing error fault bit
M748->Y:$3C0,8,1       ; Motor 7 Phasing error fault bit
M848->Y:$440,8,1       ; Motor 8 Phasing error fault bit

M129->Y:$BC,0,24,U     ; Motor 1 Direct Current-Loop Integrator Output
M229->Y:$13C,0,24,U    ; Motor 2 Direct Current-Loop Integrator Output
M329->Y:$1BC,0,24,U    ; Motor 3 Direct Current-Loop Integrator Output
M429->Y:$23C,0,24,U    ; Motor 4 Direct Current-Loop Integrator Output
M529->Y:$2BC,0,24,U    ; Motor 5 Direct Current-Loop Integrator Output
M629->Y:$33C,0,24,U    ; Motor 6 Direct Current-Loop Integrator Output
M729->Y:$3BC,0,24,U    ; Motor 7 Direct Current-Loop Integrator Output
M829->Y:$43C,0,24,U    ; Motor 8 Direct Current-Loop Integrator Output

I196,8,100=1           ; Turbo PMAC PWM control for Brush motor.
                       ; The tuning software disables PLCs if not told otherwise.
                       ; This will ensure zero direct current loop output tuning

Open plc 1 clear
If (M148=1)
 CMD"M148,8,100=0"             ; Clear Phasing Error Bit
EndIF
M129=0 M229=0 M329=0 M429=0    ; Axis1-4 Zero Current-Loop Integrator Output
M529=0 M629=0 M729=0 M829=0    ; Axis5-8 Zero Current-Loop Integrator Output
Close                          ; For Brush Motor Control, PLC has to be executing periodically
```

Note

Remember to configure the Tuning software to allow this PLC to run while performing position loop tuning.

Commutation Enable, Phase Angle, Current Mask: Ixx01, Ixx72, Ixx84

```
I101,8,100=1           ; Motors 1-8 Commutation enabled
I172,8,100=1536        ; Motors 1-8 Commutation phase angle (Geo Brick Drive specific)
I184,8,100=$FFF000     ; Motors 1-8 Current-Loop Feedback Mask Word (Geo Brick Drive specific)
```

PWM Scale Factor: Ixx66

If Motor Rated Voltage > Bus Voltage:

```
I166=1.10*I7000       ; Motor #4 PWM Scale Factor. Set to 10% above PWM Count.
I266=I166 I366=I166 I466=I166 I566=I166      ; Assuming same motor(s) as motor #1
I666=I166 I766=I166 I866=I166                ; Assuming same motor(s) as motor #1
```

If Bus Voltage > Motor Rated Voltage:

Ixx66 acts as a voltage limiter (command from PMAC to power block). In order to obtain full voltage output it is set to about 10% over PWM count divided by DC Bus/Motor voltage ratio:

```
#define DCBusInput     170     ; DC Bus Voltage [VDC] = 1.414* 110 VAC -User Input

#define Mtr1Voltage    24      ; Motor 1 Rated Voltage [VDC] -User Input
#define Mtr2Voltage    24      ; Motor 2 Rated Voltage [VDC] -User Input
#define Mtr3Voltage    24      ; Motor 3 Rated Voltage [VDC] -User Input
#define Mtr4Voltage    24      ; Motor 4 Rated Voltage [VDC] -User Input
#define Mtr5Voltage    24      ; Motor 5 Rated Voltage [VDC] -User Input
#define Mtr6Voltage    24      ; Motor 6 Rated Voltage [VDC] -User Input
#define Mtr7Voltage    24      ; Motor 7 Rated Voltage [VDC] -User Input
#define Mtr8Voltage    24      ; Motor 8 Rated Voltage [VDC] -User Input

I166=1.10*I7000*Mtr1Voltage/DCBusInput       ; Motor 1 PWM Scale Factor
I266=1.10*I7000*Mtr2Voltage/DCBusInput       ; Motor 2 PWM Scale Factor
I366=1.10*I7000*Mtr3Voltage/DCBusInput       ; Motor 3 PWM Scale Factor
I466=1.10*I7000*Mtr4Voltage/DCBusInput       ; Motor 4 PWM Scale Factor
I566=1.10*I7000*Mtr5Voltage/DCBusInput       ; Motor 5 PWM Scale Factor
I666=1.10*I7000*Mtr6Voltage/DCBusInput       ; Motor 6 PWM Scale Factor
I766=1.10*I7000*Mtr7Voltage/DCBusInput       ; Motor 7 PWM Scale Factor
I866=1.10*I7000*Mtr8Voltage/DCBusInput       ; Motor 8 PWM Scale Factor
```

Current Feedback Address: Ixx82

```
I182=$078006   ; Motor 1 Current Feedback Address
I282=$07800E   ; Motor 2 Current Feedback Address
I382=$078016   ; Motor 3 Current Feedback Address
I482=$07801E   ; Motor 4 Current Feedback Address
I582=$078106   ; Motor 5 Current Feedback Address
I682=$07810E   ; Motor 6 Current Feedback Address
I782=$078116   ; Motor 7 Current Feedback Address
I882=$07811E   ; Motor 8 Current Feedback Address
```

Commutation Cycle Size: Ixx70, Ixx71

Set to zero with DC brush motors, commutation is done mechanically.

```
I170=0 I171=0  ; Motor 1 size and number of commutation cycles
I270=0 I271=0  ; Motor 2 size and number of commutation cycles
I370=0 I371=0  ; Motor 3 size and number of commutation cycles
I470=0 I471=0  ; Motor 4 size and number of commutation cycles
I570=0 I571=0  ; Motor 5 size and number of commutation cycles
I670=0 I671=0  ; Motor 6 size and number of commutation cycles
I770=0 I771=0  ; Motor 7 size and number of commutation cycles
I870=0 I871=0  ; Motor 8 size and number of commutation cycles
```

I2T Protection: Ixx57, Ixx58, Ixx69

The lower values (tighter specifications) of the Continuous/Instantaneous current ratings between the Geo Brick Drive and motor are chosen to setup I2T protection.

If the peak current limit chosen is that of the Geo Brick Drive (possible values 10, 16, or 30 Amps) then the time allowed at peak current is set to 2 seconds.

If the peak current limit chosen is that of the Motor, check the motor specifications for time allowed at peak current.

Examples:

- For setting up I2T on a 5/10-Amp Geo Brick Drive driving a 3/9-Amp motor, 3 amps continuous and 9 amps instantaneous will be used as current limits. And time allowed at peak is that of the motor.
- For setting up I2T on a 5/10-Amp Geo Brick Drive driving an 8/16-Amp motor, 5 amps continuous and 10 amps instantaneous will be used as current limits. And time allowed at peak is 2 seconds.
- For setting up I2T on a 15/30-Amp channel on a Geo Brick Drive driving a 12/45-Amp motor, 12 amps continuous and 30 amps instantaneous will be used as current limits. And Time allowed at peak is 2 seconds.

An 8-axis 5/10-Amp Geo Brick Drive driving 3/9-amp motors:

```
I15=0                          ; Trigonometric calculation in degrees
#define ServoClk       P7003   ; [KHz] Computed in Dominant Clock Settings Section
#define ContCurrent    3       ; Continuous Current Limit [Amps] -User Input
#define PeakCurrent    9       ; Instantaneous Current Limit [Amps] -User Input
#define MaxADC         16.26   ; =16.26 for 5/10A  -User Input, see electrical specs
                               ; =26.02 for 8/16A  -User Input, see electrical specs
                               ; =48.08 for 15/30A -User Input, see electrical specs
#define I2TOnTime      2       ; Time allowed at peak Current [sec] -User Input

I157=INT(32767*(ContCurrent*1.414/MaxADC)*cos(30))
I169=INT(32767*(PeakCurrent*1.414/MaxADC)*cos(30))
I158=INT((I169*I169-I157*I157)*ServoClk*1000*I2TOnTime/(32767*32767))

I257=I157      I258=I158      I269=I169
I357=I157      I358=I158      I369=I169
I457=I157      I458=I158      I469=I169
I557=I157      I558=I158      I569=I169
I657=I157      I658=I158      I669=I169
I757=I157      I758=I158      I769=I169
I857=I157      I858=I158      I869=I169
```

Note

This (software) I2T protection is handled by the PMAC to protect the motor equipment. The Geo Brick Drive has its own built-in hardware I2T as an additional layer of safety and self protection.

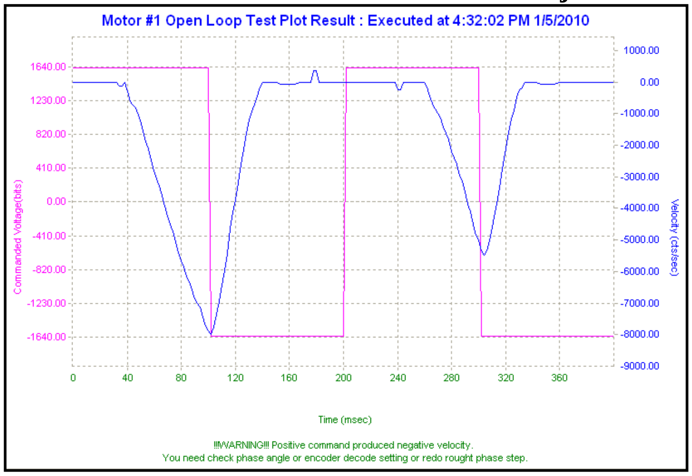
ADC Offsets: Ixx29, Ixx79

The ADC offsets importance may vary from one system to another, depending on the motor(s) type and application requirements. They can be left at default of zero especially if a motor setup is to be reproduced on multiple machines by copying the configuration file of the first time integration. However, they should ultimately be set to minimize measurement offsets from the A and B-phase current feedback circuits, respectively (read in Suggested M-variables Mxx05, Mxx06).

Current-Loop Gains, Open-Loop/Enc. Decode: Ixx61, Ixx62, Ixx76, I7mn0

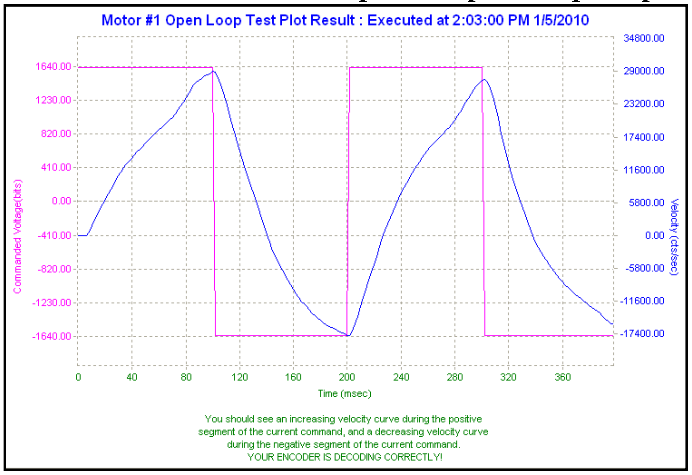
Tuning (fine) the current loop with DC brush motors is neither critical nor required. Set Ixx61 to a conservative value (i.e. 0.001) and perform an open-loop test. Essentially a positive open loop command should result in position direction (of the encoder) motion and vice-versa:

Reversed Encoder Decode. I7mn0 needs adjustment



Once the Encoder Decode is verified, increment Ixx61 gradually and redo the Open-Loop test until a solid saw tooth response is observed. Note that further increasing Ixx61 will not improve the performance.

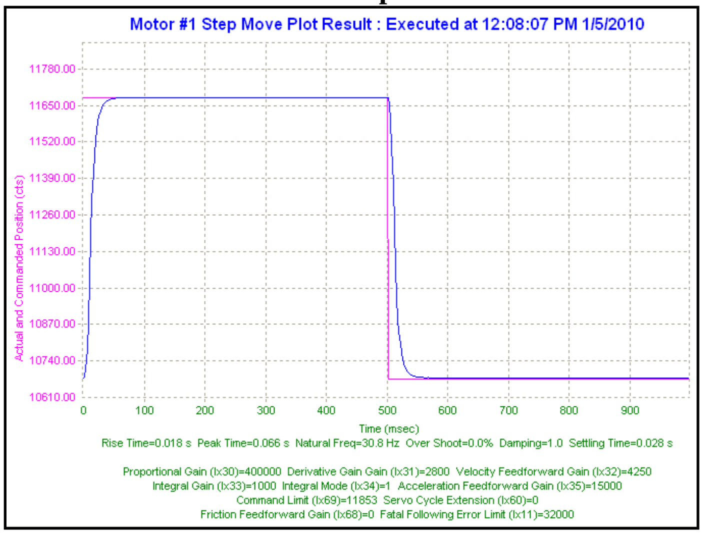
Correct Encoder Decode-Acceptable Open-Loop Response



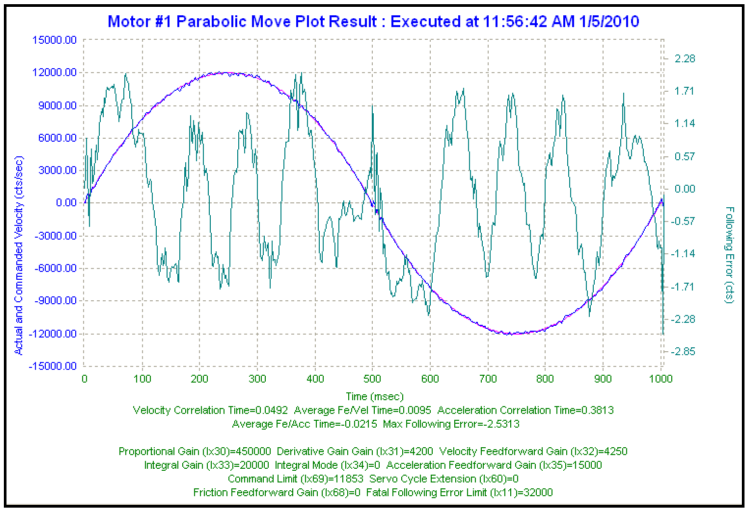
Position-Loop PID Gains: Ixx30…Ixx39

The position-loop tuning is done as in any Turbo PMAC PID-Loop setup. The PMACTuningPro2 automatic or interactive utility can be used to fine-tune the PID-Loop. Acceptable Step and Parabolic position responses would look like:

Position Step Move



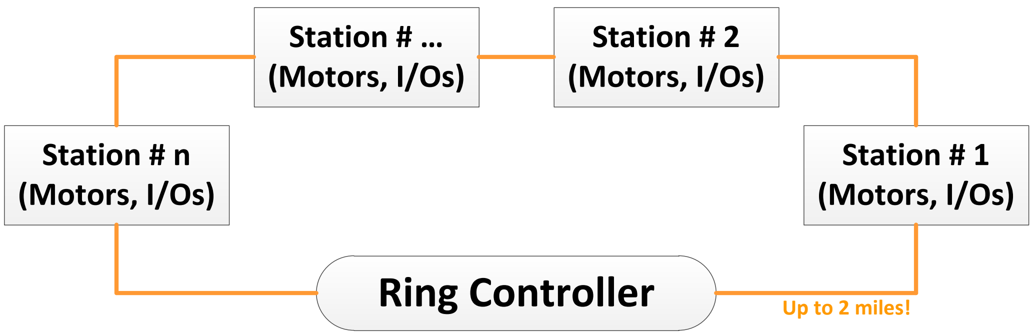
Position Parabolic Move



MACRO CONNECTIVITY

Introduction To MACRO

MACRO Ring For Distributed Motion Control - www.macro.org -



MACRO stands for **M**otion and **C**ontrol **R**ing **O**ptical. It is a high bandwidth non-proprietary digital interface industrialized by Delta Tau Data Systems for distributed multi-axis systems.
MACRO can be connected using either fiber optic or twisted copper pair RJ45 cables. The RJ45 electrical interface can extend to up to 30 meters (or about 100 feet), and the fiber optic interface can extend to up to 3 kilometers (or about 2 miles). **MACRO** features:

- **Noise Immunity**: MACRO transfers data using light rather than electricity which renders it immune to electromagnetic noise and capacitive coupling.
- **Wiring Simplicity**: Single-plug connection between controllers, amplifiers, and I/O modules minimizing wiring complexity in large systems.
- **High Speed**: data transfer rate at 125 Megabits per second, and servo update rates as high as 65 KHz.
- **Centralized, Synchronized Control**: No software intervention is required on the MACRO stations. One or multiple rings can be controlled, synchronized, and accessed using a single ring controller.

MACRO Ring Configurations

The Geo Brick Drive, with the optional MACRO interface, supports a wide variety of MACRO ring formations. This section describes some of the most popular configurations:

Example	MACRO Ring Controller (Master)	MACRO Ring Slave(s)
1	Geo Brick Drive	Geo Brick Drive
2	Geo Brick drive	Geo MACRO Drive

Note

In certain cases, configuring a MACRO ring may require communicating (via USB, Ethernet, or serial) separately to either or both; the Ring Master, and Ring Slave.

Note

The Geo Brick Drive can only carry up to 1 MACRO IC, which consists of 8 servo nodes (motors) and 12 I/O nodes (432 I/O points)

MACRO Configuration Example 1

This Configuration supports two modes:

- **Torque Mode**: Most commonly used and highly recommended due to setup simplicity and computational load sharing between Master and Slave.
  In this mode, the Master closes strictly the position loop and sends torque commands to the Slave. The Slave closes the current loop and handles the commutation of the motor.

- **PWM Mode**: Useful when centralized commutation and tuning (current & PID) are desirable. However, if the application involves Kinematics and/or high computation frequency, Torque Mode is advised.
  In this mode, the Master bypasses the Slave control functions. The Master handles the commutation, it closes both the current and position loops, sending finally PWM commands directly to the Slaves' power amplifier block.

In either mode, Master-Slave data exchange (i.e. write, read) can be achieved using Macro Auxiliary MX commands:

To read: MX{node #},M{slave var}
To write: MX{node #},M{slave var}={constant}

{node #} is a constant in the range 0 to 15 representing the number of the node.

M{slave var} is the name of the variable at the Macro Slave. It can be an I, P, Q, or M-variable with a number from 0 to 8191.

Setting Up Slave Station in Torque Mode

1. Establish communication to Slave unit using USB, Ethernet, or Serial.

2. Reset to factory default for new configuration setup. Issue a $$$***, Save, and a $$$.

3. Setup local motors manually or using one of the available automatic setup software utilities (i.e. Geo Brick Drive setup). Clock settings in this step have to be considered carefully and respect the following:

    - Macro IC0 clock settings must be the same as the predominant Servo IC0:

```
I6800=I7000     ; Macro IC0 MaxPhase/PWM Frequency Control
I6801=I7001     ; Macro IC0 Phase Clock Frequency Control
I6802=I7002     ; Macro IC0 Servo Clock Frequency Control
```

    - Make sure that the servo interrupt time I10 is setup correctly.
    - Phase Clock has to be the same for both Master and Slave

4. Make sure the motors are operational after a Save and $$$. Fine tuning only applies to the current loop on the slave side; the position loop should be fine-tuned on the master side.

5. Kill all motors

6. Clock source direction, Macro configuration, Node activation, Command address

```
I19=6807                ; Macro IC0 source of Phase and Servo
I6840=$4080             ; Macro IC0 Ring Configuration/Status
I6841=$0FF333           ; Macro IC0 Node Activate Ctrl (servo nodes 0, 1, 4, 5, 8, 9, 12, 13)

I144=$178423            ; Macro IC0 Node 0 Command Address. Torque Mode
I244=$178427            ; Macro IC0 Node 1 Command Address. Torque Mode
I344=$17842B            ; Macro IC0 Node 4 Command Address. Torque Mode
I444=$17842F            ; Macro IC0 Node 5 Command Address. Torque Mode
I544=$178433            ; Macro IC0 Node 8 Command Address. Torque Mode
I644=$178437            ; Macro IC0 Node 9 Command Address. Torque Mode
I744=$17843B            ; Macro IC0 Node 12 Command Address. Torque Mode
I844=$17843F            ; Macro IC0 Node 13 Command Address. Torque Mode
```

Note

With Ixx44 set to 0, the Slave has full control of the motor(s).
Setting Ixx44 to $1784xx will redirect the torque control to the Master prohibiting any control on the motor(s) from the slave side (firmware version 1.948 or later).

7. Ring Error Check

```
#define RingCheckPeriod       20            ; Suggested Ring Check Period [msec]
#define FatalPackErr          10            ; Suggested Fatal Packet Error Percentage [%]

I80=RingCheckPeriod *8388607/I10+1          ; Macro Ring Check Period [Servo Cycles]
I81=I80/(I8+1)* FatalPackErr /100           ; Macro Maximum Ring Error Count
I82=I80/(I8+1)*(100-FatalPackErr)/100       ; Macro Minimum Sync Packet Count
```

8. Issue a Save, and a $$$ to maintain changes.

The motors attached to the slave(s) have to be phased locally before allowing the Master to take over their control. This can be done using Macro auxiliary MX commands. Creating a handshaking flag to trigger local phasing followed by a kill on the slave side can be executed in a simple PLC.

Slave Handshaking PLC Example: Phase then kill Motor#1

```
End Gat
Del Gat
Close

// Substitutions and definitions
#define Mtr1MSCont     I144          ; #1 MACRO Slave Control
#define CS1Timer1      I5111         ; Coordinate System 10 Countdown timer1
#define Mtr1PhaseFlag  P8000         ; User Flag to Phase Motor1
#define Mtr1DesVelZero M133          ; #1 Desired-velocity-zero bit
#define Mtr1InPosTrue  M140          ; #1 Background in-position bit

I5=I5|2                              ; Allow Background PLC's
Mtr1MSCont= $178423
Mtr1PhaseFlag= 0
Mtr1DesVelZero->X:$0000B0,13,1       ; Mtr1 Desired Velocity bit
Mtr1InPosTrue->Y:$0000C0,0,1         ; Mtr1 In-position bit

// Example PLC to phase and kill Motor 1 (by setting P8000=1 from MACRO Master side)
Open plc 1 clear
If (Mtr1PhaseFlag=1)
 Mtr1MSCont= 0
 Mtr1PhaseFlag= 0
 CS1Timer1= 50*8388608/I10 While(CS1Timer1>0) Endw
 CMD"#1$"
 CS1Timer1= 50*8388608/I10 While(CS1Timer1>0) Endw
 While(Mtr1DesVelZero=0 or Mtr1InPosTrue=0) Endw
 CMD"#1K"
 CS1Timer1= 50*8388608/I10 While(CS1Timer1>0) Endw
 Mtr1MSCont= $178423
 CS1Timer1= 50*8388608/I10 While(CS1Timer1>0) Endw
EndIf
Close
```

Note

Issuing MX0, P8000=1 from the Master will allow the execution of this code on the slave.

Setting Up Master Station in Torque Mode

1. Establish communication to Master unit using USB, Ethernet, or Serial.

2. Reset to factory default for new configuration setup. Issue a $$$***, Save, and a $$$.

3. Setup local motors manually or using one of the available automatic setup software utilities (i.e. Geo Brick Drive Setup). Clock settings in this step have to be considered carefully and respect the following:
   - Macro IC0 clock settings must be the same as the predominant Servo IC0:

```
I6800=I7000     ; Macro IC0 MaxPhase/PWM Frequency Control
I6801=I7001     ; Macro IC0 Phase Clock Frequency Control
I6802=I7002     ; Macro IC0 Servo Clock Frequency Control
```

   - Make sure that the servo interrupt time I10 is setup correctly. The Pewin32Pro2 software (for proper functionality) has to be restarted whenever I10 is changed.
   - Phase Clock has to be the same for both Master and Slave

4. Make sure the motors are operational after a Save and a $$$. Fine tuning current and PID loops can be performed at this point if necessary.

5. Kill all motors. Local Motors 1 thru 8 are now finished.

6. Macro Configuration, servo node activation, Auxiliary register and mode

```
I6840=$4030     ; Macro IC 0 Ring Configuration/Status
I6841=$0FF333   ; Macro IC 0 Node Activate Ctrl 8-axis (servo nodes 0, 1, 4, 5, 8, 9, 12, 13)
I78=32          ; Macro Type 1 Master/Slave Communications Timeout
I70=$3333       ; Macro IC 0 Node Auxiliary Register Enable (for 8 Ring motors)
I71=0           ; Type 0 MX Mode
```

7. Ring Error Check

```
#define RingCheckPeriod       20            ; Suggested Ring Check Period [msec]
#define FatalPackErr          10            ; Suggested Fatal Packet Error Percentage [%]

I80=RingCheckPeriod *8388607/I10+1          ; Macro Ring Check Period [Servo Cycles]
I81=I80/(I8+1)* FatalPackErr /100           ; Macro Maximum Ring Error Count
I82=I80/(I8+1)*(100-FatalPackErr)/100       ; Macro Minimum Sync Packet Count
```

8. Issue a Save, and a $$$ to maintain changes.

9. Activating Ring Motors, Flag Mode Control
   Variable I4900 reports which Servo IC's are present in a Brick or Turbo PMAC controller. Knowing that each Servo IC services 4 axes, querying I4900 will reveal how many local channels are occupied and thus the number of the 1st available motor on a Macro Ring:

If I4900 returns	Servo ICs present	Local Motors	First Ring Motor#
$0	None	None	1
$1	IC0 only (4-axis)	1 thru 4	5
$3	IC0, and IC1(8-axis)	1 thru 8	9

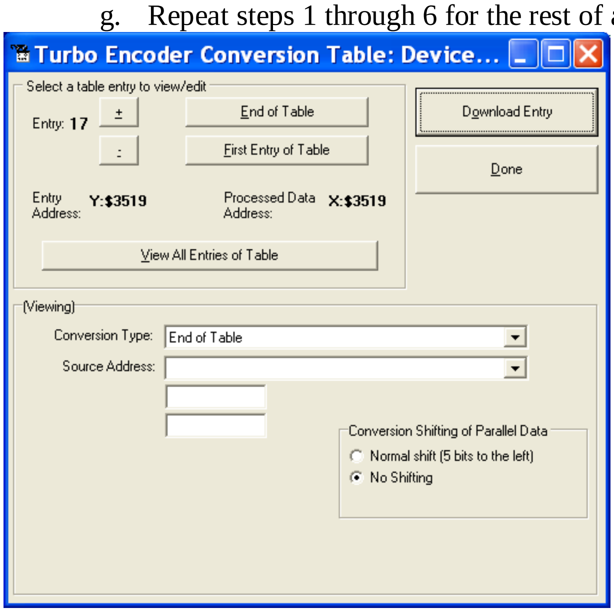
Activation 8-axis Slave	Flag Mode Control
I100,8,100=1	I124,8,100=$40001
I500,8,100=1	I524,8,100=$40001
I900,8,100=1	I924,8,100=$40001

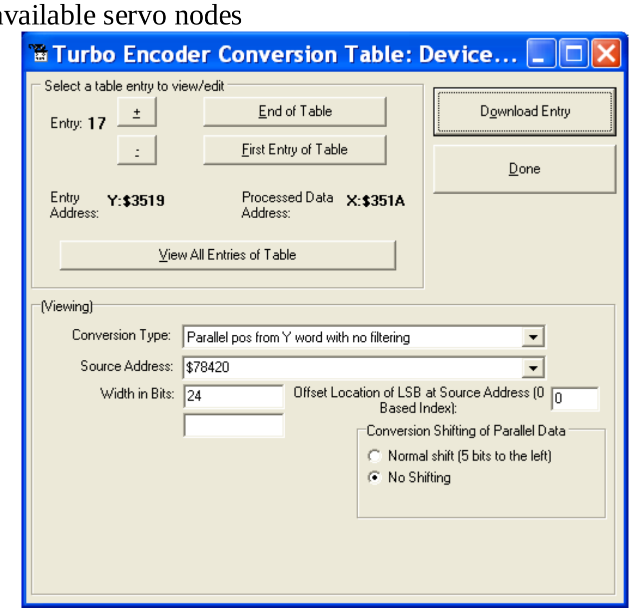
10. Ring Motors' Position & Velocity Pointers.
If all local motors have digital quadrature encoders (1-line entries), and no other entries are used in the Encoder Conversion Table then the position Ixx03 and Velocity Ixx04 pointers of the motors on the ring should be valid by default.

Motor on the ring	Ixx03, Ixx04
First	$350A
Second	$350C
Third	$350E
Fourth	$3510
Fifth	$3512
Sixth	$3514
Seventh	$3516
Eighth	$3518

However, if the Master Encoder Conversion Table has been modified or special feedback devices, i.e. sinusoidal, EnDat, SSI etc. (requiring more than 1-line entries) are mounted on local motors then the Encoder Conversion Table entries for Macro servo nodes have to be setup properly. And the position Ixx03 and Velocity Ixx04 pointers of the motors on the ring have to be adjusted accordingly. We will do this using the Encoder Conversion Table utility in the PewinPro2 under Configure>Encoder Conversion Table:

a. Click on End of Table to access the first available entry
b. Conversion Type: Parallel position from Y word with no filtering
c. No Shifting
d. Width in Bits: 24
e. Source Address: This is the Servo node Address (See table below)
f. Record Processed Data Address. This is where the position & velocity pointers will be set to for a specific node/motor number. In the example illustrated below, Ixx03 & Ixx04 will be equal to $351A
g. Repeat steps 1 through 6 for the rest of available servo nodes





Servo Node Address

Motor on the ring	Address	Register
First	$78420	Macro IC 0 Servo Node 0
Second	$78424	Macro IC 0 Servo Node 1
Third	$78428	Macro IC 0 Servo Node 4
Fourth	$7842C	Macro IC 0 Servo Node 5
Fifth	$78430	Macro IC 0 Servo Node 8
Sixth	$78434	Macro IC 0 Servo Node 9
Seventh	$78438	Macro IC 0 Servo Node 12
Eighth	$7843C	Macro IC 0 Servo Node 13

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window

11. Flag Address
    The Flag addresses for Ring motors are initiated by default in the firmware. No need to make any changes:

Motor on the ring (Ixx25)	Value	Register
First	$3440	MACRO Flag Register Set 0
Second	$3441	MACRO Flag Register Set 1
Third	$3444	MACRO Flag Register Set 4
Fourth	$3445	MACRO Flag Register Set 5
Fifth	$3448	MACRO Flag Register Set 8
Sixth	$3449	MACRO Flag Register Set 9
Seventh	$344C	MACRO Flag Register Set 12
Eighth	$344D	MACRO Flag Register Set 13

12. Issue MX0, P8000=1 to phase and kill selected motor(s) on the slave. These are the motors included in the related Slave PLC.

13. Tuning the PID-Loop on Ring motors.
    The PID gains saved on the slave at the initial setup can be used as a starting point.

Setting Up Slave Station in PWM Mode

1. Establish communication to Slave unit using USB, Ethernet, or Serial.

2. Reset to factory default for new configuration setup. Issue a $$$***, Save, and a $$$.

3. Set Clock Source to Macro IC0 (I19)

```
I19=6807        ; Macro IC0 source of Servo and Phase
```

4. Macro configuration, enable servo nodes, flag mode control, command address

```
I6840=$4080           ; Macro IC 0 Ring Configuration/Status
I6841=$0FF333         ; Macro IC 0 Node Activate Ctrl (servo nodes 0, 1, 4, 5, 8, 9, 12, and 13)
I124,8,100=$800001    ; Flag mode control (=$1 for Brick AC & Brick Controller)

I144=$078423          ; MacroIC0 Node 0 Command Address. PWM Mode
I244=$078427          ; MacroIC0 Node 1 Command Address. PWM Mode
I344=$07842B          ; MacroIC0 Node 4 Command Address. PWM Mode
I444=$07842F          ; MacroIC0 Node 5 Command Address. PWM Mode
I544=$078433          ; MacroIC0 Node 8 Command Address. PWM Mode
I644=$078437          ; MacroIC0 Node 9 Command Address. PWM Mode
I744=$07843B          ; MacroIC0 Node12 Command Address. PWM Mode
I844=$07843F          ; MacroIC0 Node13 Command Address. PWM Mode
```

5. Issue a Save and a $$$ to maintain changes.

Setting Up Master Station in PWM Mode

1. Establish communication to Master unit using USB, Ethernet, or Serial.

2. Reset to factory default for new configuration setup. Issue a $$$***, Save, and a $$$.

3. Setup local motors manually or using one of the available automatic setup software utilities (i.e. Geo Brick Setup). Clock settings in this step have to be considered carefully and respect the following:
   - Macro clock settings have to be the same as of the predominant Servo IC0:

```
I6800=I7000     ; Macro IC0 MaxPhase/PWM Frequency Control
I6801=I7001     ; Macro IC0 Phase Clock Frequency Control
I6802=I7002     ; Macro IC0 Servo Clock Frequency Control
```

   - Make sure that the servo interrupt time I10 is setup correctly.
   - Phase Clock has to be the same for both Master and Slave

4. Make sure the motors are operational after a Save and a $$$. Current and PID loops fine tuning can be performed at this point if necessary.

5. Kill all motors. Local motors 1 through 8 are now finished.

6. Macro Configuration, servo node activation, Auxiliary register and mode

```
I6840=$4030     ; Macro IC 0 Ring Configuration/Status
I6841=$0FC033   ; Macro IC 0 Node Activate Ctrl 8-axis (servo nodes 0, 1, 4, 5, 8, 9, 12, 13)
I78=32          ; Macro Type 1 Master/Slave Communications Timeout
I70=$3333       ; Macro IC 0 Node Auxiliary Register Enable (for 8 Ring motors)
I71=0           ; Type 0 MX Mode
```

7. Ring Error Check

```
#define RingCheckPeriod       20              ; Suggested Ring Check Period [msec]
#define FatalPackErr          10              ; Suggested Fatal Packet Error Percentage [%]

I80=RingCheckPeriod *8388607/I10+1            ; Macro Ring Check Period [Servo Cycles]
I81=I80/(I8+1)* FatalPackErr /100             ; Macro Maximum Ring Error Count
I82=I80/(I8+1)*(100-FatalPackErr)/100         ; Macro Minimum Sync Packet Count
```

8. Issue a Save, and a $$$ to maintain changes.

9. Activating Ring Motors
   Variable I4900 reports which Servo IC's are present in a Brick or Turbo PMAC controller. Knowing that each Servo IC services 4 axes, querying I4900 will reveal how many local channels are occupied and thus the number of the 1st available motor on a Macro Ring:

If I4900 returns	Servo ICs present	Local Motors	First Ring Motor#
$0	None	None	1
$1	IC0 only (4-axis)	1 thru 4	5
$3	IC0, and IC1(8-axis)	1 thru 8	9

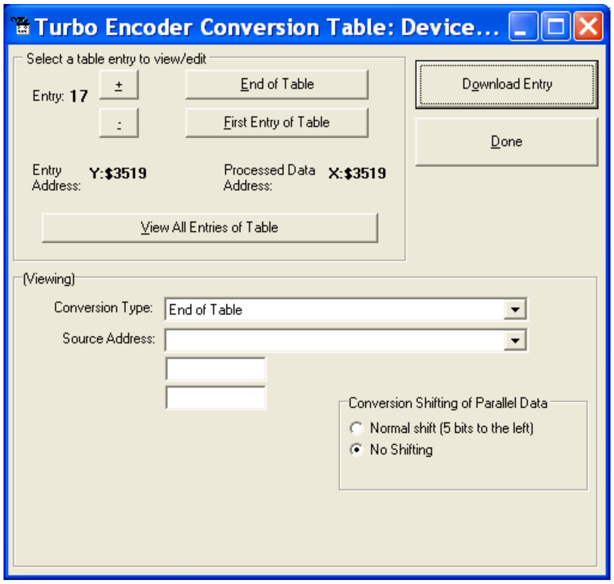
Activation 8-axis Slave	Flag Mode Control
I100,8,100=1	I124,8,100=$40001
I500,8,100=1	I524,8,100=$40001
I900,8,100=1	I924,8,100=$40001

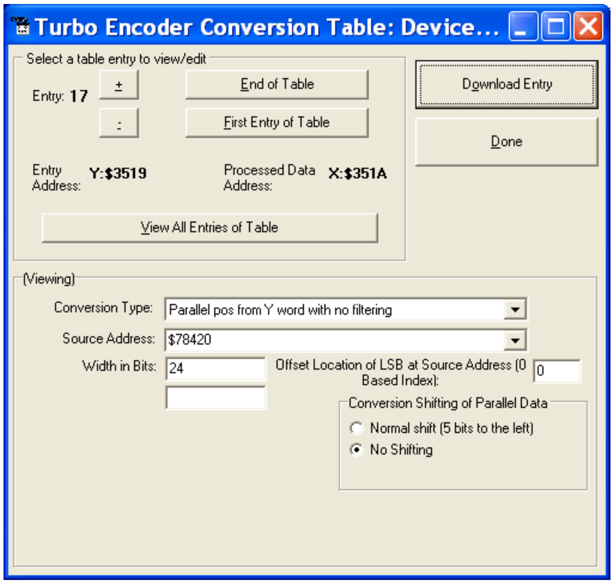
10. Ring Motors' Position & Velocity Pointers.

    If all local motors have digital quadrature encoders (1-line entries), and no other entries are used in the Encoder Conversion Table then the position Ixx03 and Velocity Ixx04 pointers of the motors on the ring should be valid by default.

    However, if the Master Encoder Conversion Table has been modified or special feedback devices, i.e. sinusoidal, EnDat etc. (requiring more than 1-line entries) are mounted on local motors then the Encoder Conversion Table entries for Macro servo nodes have to be setup properly. And the position Ixx03 and Velocity Ixx04 pointers of the motors on the ring have to be adjusted accordingly. We will do this using the Encoder Conversion Table utility in the PewinPro2 under Configure>Encoder Conversion Table:

a. Click on End of Table to access the first available entry
b. Conversion Type: Parallel position from Y word with no filtering
c. No Shifting
d. Width in Bits: 24
e. Source Address: This is the Servo node Address (See table below)
f. Record Processed Data Address. This is where the position & velocity pointers will be set to for a specific node/motor number. In the example illustrated below, Ixx03 & Ixx04 will be equal to $351A
g. Repeat steps 1 through 6 for the rest of available servo nodes





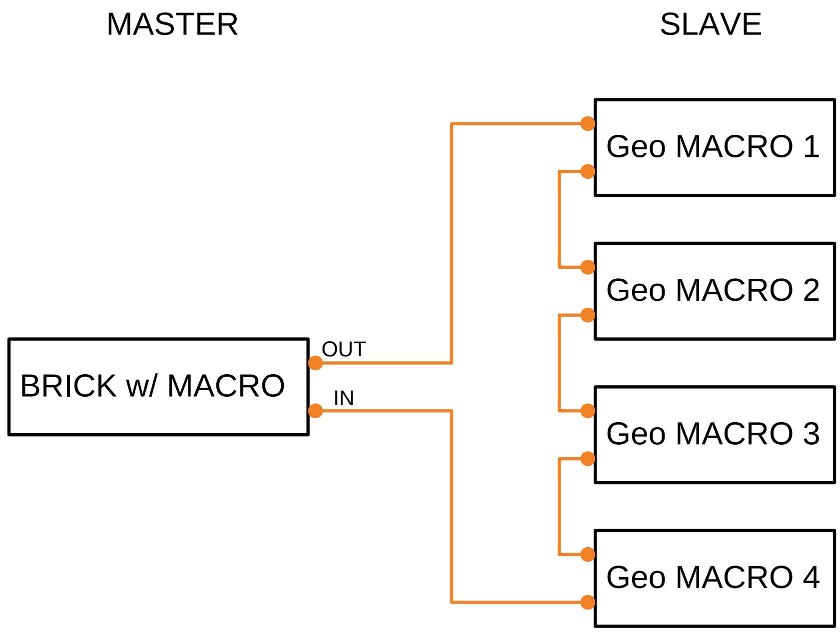
Servo Node Address

Motor on the ring	Address	Register
First	$078420	Macro IC 0 Servo Node 0
Second	$078424	Macro IC 0 Servo Node 1
Third	$078428	Macro IC 0 Servo Node 4
Fourth	$07842C	Macro IC 0 Servo Node 5
Fifth	$078430	Macro IC 0 Servo Node 8
Sixth	$078434	Macro IC 0 Servo Node 9
Seventh	$078438	Macro IC 0 Servo Node 12
Eighth	$07843C	Macro IC 0 Servo Node 13

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window.

MACRO Configuration Example 2



For simplicity, the example steps will cover guidelines for 1 Geo Macro Drive on the ring. Other available drives can be setup similarly:

1. Establish communication to the Brick using USB, Ethernet, or Serial.

2. Reset to factory default for new configuration setup. Issue a $$$***, Save, and a $$$.

3. Download Suggested M-variables (recommended)

4. Set up local motors (Motors which are directly attached to the slave). Clock settings in this step have to be considered carefully and respect the following:
   - Macro clock settings have to be the same as of the predominant Servo IC0:

```
I6800=I7000    ; Macro IC0 MaxPhase/PWM Frequency Control
I6801=I7001    ; Macro IC0 Phase Clock Frequency Control
I6802=I7002    ; Macro IC0 Servo Clock Frequency Control
```

   - Make sure that the servo interrupt time I10 is setup correctly.
   - Phase Clock has to be the same for both Master and Slave

5. Make sure the motors are operational after a Save and a $$$. Current and PID loops fine tuning can be performed at this point if necessary.

6. Kill all motors. Local motors 1 through 8 are now finished.

7. Macro Configuration, servo node activation, Auxiliary register and mode

```
I6840=$4030    ; Macro IC 0 Ring Configuration/Status
I6841=$0FC003  ; Macro IC0 Node Ctrl, 1 Geo Macro example (servo nodes 0, 1)
I78=32         ; Macro Type 1 Master/Slave Communications Timeout
I70=$3         ; Macro IC 0 Node Auxiliary Register Enable (for 2 Ring motors)
I71=$3         ; Macro IC 0 Node Protocol Type Control. Type 1 MX mode
```

8. Ring Error Check

```
#define RingCheckPeriod      20              ; Suggested Ring Check Period [msec]
#define FatalPackErr         10              ; Suggested Fatal Packet Error Percentage [%]

I80=RingCheckPeriod *8388607/I10+1           ; Macro Ring Check Period [Servo Cycles]
I81=I80/(I8+1)* FatalPackErr /100            ; Macro Maximum Ring Error Count
I82=I80/(I8+1)*(100-FatalPackErr)/100        ; Macro Minimum Sync Packet Count
```

9. Issue a Save, and a $$$ to maintain changes.

10. Issue MS$$$***15 to reset the Geo Macro drive(s) to factory default.
    Issue MSSAV15 to save factory default settings
    Issue MS$$$15 to reset drive(s)

11. Issue MACSTA255 to establish ASCII communication with the first Geo Macro Drive on the Ring (this will be the first drive connected to the Out/Transmit fiber connector). When in ASCII mode, set station number and activate servo node(s)

```
I996= $0F4003  ; Node activation (servo nodes 0, 1)
I11= 1         ; Set station number to 1 (user configurable)
```

12. Issue a CTRL-T (^T) in the terminal window to exit ASCII mode communication

13. MS, Master Slave commands should now be available for Station #1
    Issue MSSAVE0, followed by an MS$$$0 to save parameters and reset the Geo Macro Station associated with node 0.

Note

MACSTA255 will now establish ASCII communication with the next Macro drive on the ring (if applicable). Enable servo nodes, assign the next station number, and exit ASCI communication.

14. Clock Settings
    For simplicity, we will set the max phase and clock dividers the same as the ring controller, but note that the servo rate on the Geo MACRO Drive is independent and can be set to a different frequency.
    MS0, I992= Value of I7000 (or I6800) ; Max Phase Clock
    MS0, I997= Value of I7001 (or I6801) ; Phase Clock Divider
    MS0, I998= Value of I7002 (or I6802) ; Servo Clock Divider

Note

The Phase clock has to be the same as the Ring Controllers' but the Servo Clock can be different

15. Issue MSSAV0 followed by MS$$$0 to maintain changes.

16. Activating Ring Motors

Variable I4900 reports which Servo IC's are present in a Brick or Turbo PMAC controller. Knowing that each Servo IC services 4 axes, querying I4900 will reveal how many local channels are occupied and thus the number of the 1st available motor on a Macro Ring:

If I4900 returns	Servo ICs present	Local Motors	First Motor# On The Ring
\$0	None	None	1
\$1	IC0 only (4-axis)	1 thru 4	5
\$3	IC0, and IC1(8-axis)	1 thru 8	9

Activation 2-axis Slave
`I100,2,100=1`
`I500,2,100=1`
`I900,2,100=1`

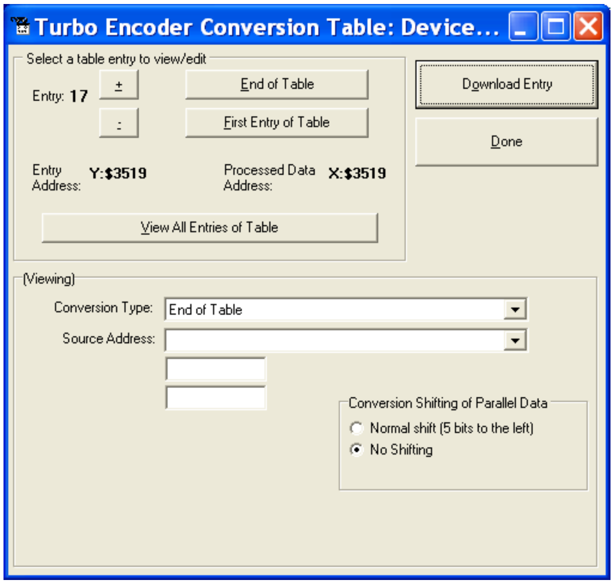
17. Position, Velocity pointers. Encoder Conversion Table

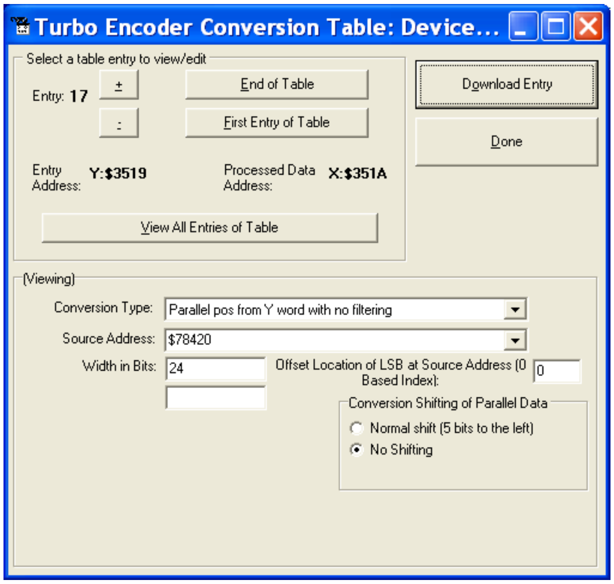
If all local motors have digital quadrature encoders (1-line entries), and no other entries are used in the Encoder Conversion Table then the position Ixx03 and Velocity Ixx04 pointers of the motors on the ring should be valid by default.

Motor # On the Ring	Position & Velocity Pointers (default)
First	\$350A
Second	\$350C
Third	\$350E
Fourth	\$3510
Fifth	\$3512
Sixth	\$3514
Seventh	\$3516
Eighth	\$3518

However, if the Master Encoder Conversion Table has been modified or special feedback devices, i.e. sinusoidal, EnDat etc. (requiring more than 1-line entries) are mounted on local motors then the Encoder Conversion Table entries for Macro servo nodes have to be setup properly. And the position Ixx03 and Velocity Ixx04 pointers of the motors on the ring have to be adjusted accordingly. We will do this using the Encoder Conversion Table utility in the PewinPro2 under Configure>Encoder Conversion Table:

a. Click on End of Table to access the first available entry
b. Conversion Type: Parallel position from Y word with no filtering
c. No Shifting
d. Width in Bits: 24
e. Source Address: This is the Servo node Address (See table below)
f. Record Processed Data Address. This is where the position & velocity pointers will be set to for a specific node/motor number. In the example illustrated below, Ixx03 & Ixx04 will be equal to \$351A
g. Repeat steps 1 through 6 for the rest of available servo nodes





Motor # On the Ring	Servo Node Address	Register
First	$078420	Macro IC 0 Servo Node 0
Second	$078424	Macro IC 0 Servo Node 1
Third	$078428	Macro IC 0 Servo Node 4
Fourth	$07842C	Macro IC 0 Servo Node 5
Fifth	$078430	Macro IC 0 Servo Node 8
Sixth	$078434	Macro IC 0 Servo Node 9
Seventh	$078438	Macro IC 0 Servo Node 12
Eighth	$07843C	Macro IC 0 Servo Node 13

Note

Additional parameters might be required for optional sinusoidal feedback in Geo Macro Drives (see Geo Macro Drive manual)

Note

At this point of the setup process, you should be able to move the motor/encoder shaft by hand and see encoder counts in the position window

18. The following motor parameters must be set up properly:

- Commutation enable (Ixx01)
  Ixx01=3 ; Over MACRO

- Flag Control (Ixx24)

\$40001	Overtravel limits enabled
\$60001	Overtravel limits disabled

- Current-Loop Feedback Address (Ixx82)

Motor # On the Ring	Ixx82	Register
First	\$078422	MACRO IC 0 Node 0
Second	\$078426	MACRO IC 0 Node 1
Third	\$07842A	MACRO IC 0 Node 4
Fourth	\$07842E	MACRO IC 0 Node 5
Fifth	\$078432	MACRO IC 0 Node 8
Sixth	\$078436	MACRO IC 0 Node 9
Seventh	\$07843A	MACRO IC 0 Node 12
Eighth	\$07843E	MACRO IC 0 Node 13

- Current-Loop Feedback Mask Word (Ixx84)
  Ixx84=\$FFF000 ; 12-bit ADCs

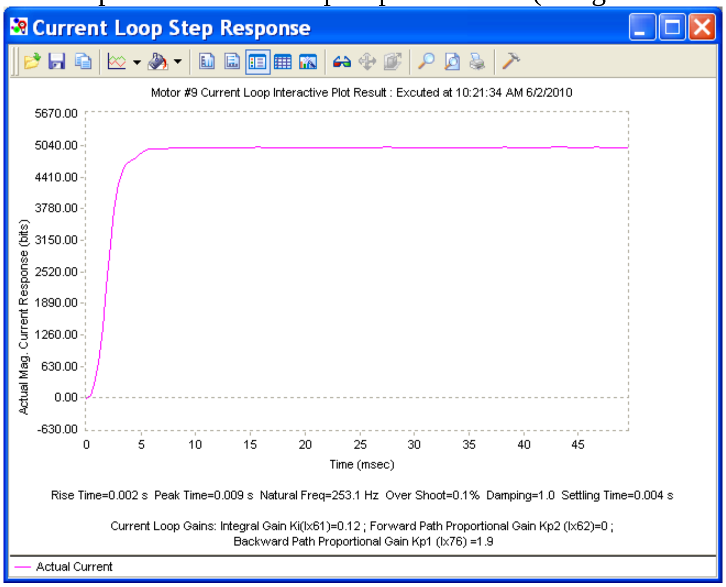
- PWM Scale Facto (Ixx66)
  Ixx66=16384 ; Geo MACRO Drives' specific setting

- Commutation Cycle Size (Ixx70, Ixx71)
  Ixx70= Number of pole pairs
  Ixx71= Number of counts per revolution *** 32**

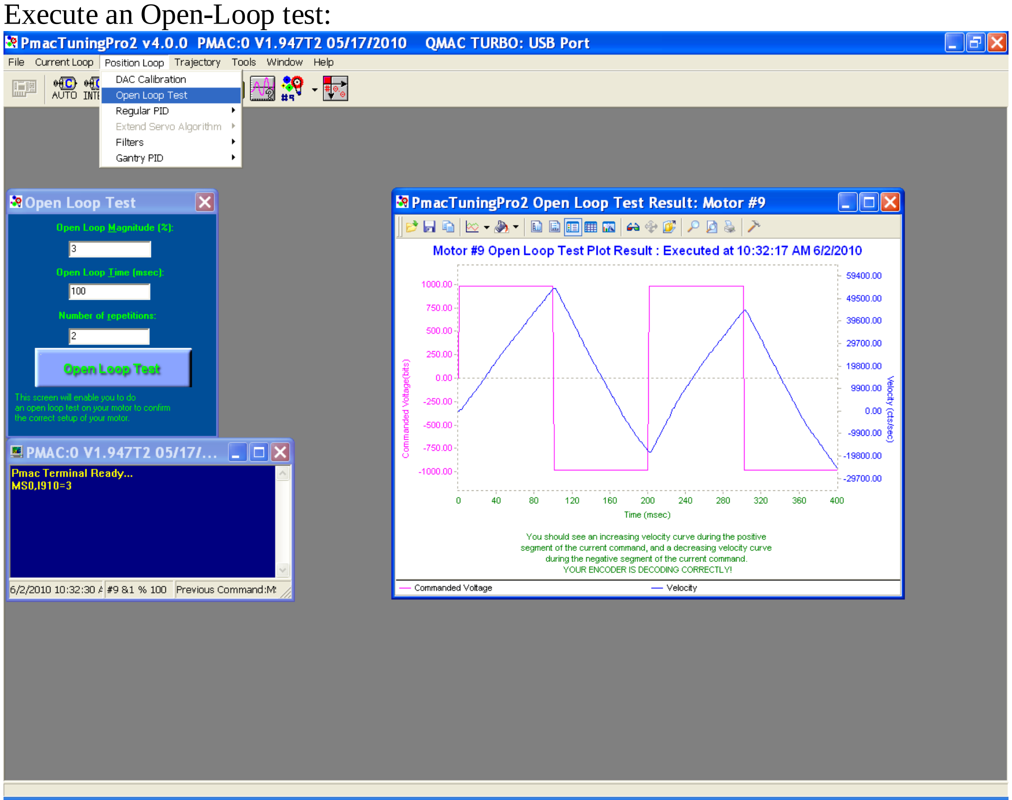
- I2T Settings (Motor #9 example)

```
I15=0                          ; Trigonometric calculation in degrees
#define MaxPhaseFreq   P7000   ; Max Phase Clock [KHz]
#define PWMClk         P7001   ; PWM Clock [KHz]
#define PhaseClk       P7002   ; Phase Clock [KHz]
#define ServoClk       P7003   ; Servo Clock [KHz]
MaxPhaseFreq=117964.8/(2*I6800+3)
PWMClk=117964.8/(4*I6800+6)
PhaseClk=MaxPhaseFreq/(I6801+1)
ServoClk=PhaseClk/(I6802+1)

#define Mtr9ContCurrent       3       ; Continuous Current Limit [Amps] -User Input
#define Mtr9PeakCurrent       9       ; Instantaneous Current Limit [Amps] -User Input
#define MaxADC                16.3    ; See Geo MACRO electrical specifications -User Input
#define Mtr9I2TOnTime         2       ; Time allowed at peak Current [sec]

// Assuming that motor 9 is the first motor on MACRO
I957=INT(32767*(Mtr9ContCurrent*1.414/MaxADC)*cos(30))
I969=INT(32767*(Mtr9PeakCurrent*1.414/MaxADC)*cos(30))
I958=INT((I969*I969-I957*I957)*ServoClk*1000*Mtr9I2TOnTime/(32767*32767))
```

19. Current-Loop Tuning (Ixx61, Ixx62, Ixx76)
    An acceptable Current-Loop step would like (using the PmacTuningPro2):

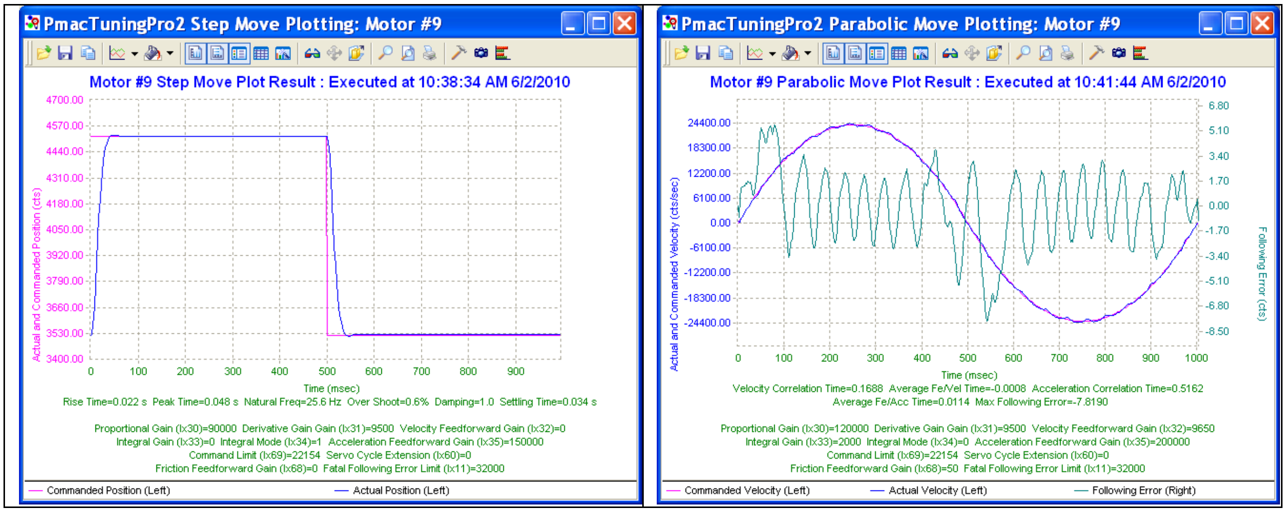


20. Motor Phasing, Open-Loop Test
    It is advised at this point to try to phase the motor manually. Refer to the "Motor Phasing Section" for this procedure (remember to clear the phasing search error bit, set Mxx48=0). Execute an Open-Loop test:



If you see an erratic response, or an inverted saw tooth, then most likely the encoder/decode is incorrect. This is on the MACRO side, **MS{node},MI910** has to be changed from 7 to 3 or vice versa.

21. Position-Loop PID tuning
    Acceptable step and parabolic moves (using the PmacTuningPro2) would look like:



MACRO I/O Transfer

This section describes the copying (reading and writing to) of digital general purpose I/Os from a Brick Macro Station to “any” MACRO Ring Controller.

Traditionally, Each Macro I/O node supports up to 72 bits of data transfer between Ring Controller and Station(s). For simplicity, we will choose I/O node 2 as an example of data transfer using three 16-bit registers.

I/O Node	2	Description
X:$78420	24-bit	24-bit register
X:$78421	16-bit	1st 16-bit register (Upper)
X:$78422	16-bit	2nd16-bit register (Upper)
X:$78423	16-bit	3rd 16-bit register (Upper)

A Brick Macro Station can have up to 32 Inputs and 16 Outputs (connectors J6, and expanded J7). The first 16-bit register will be used to transfer Outputs. The second and third 16-bit registers will be used to transfer Inputs. The 24-bit register will be left blank, and can be used for other transfers.

Slave Station I/O Setup Example

```
End Gat
Del Gat
Close
I5=I5|2                         ; Allow background PLC's
I6841=I6841|$000004             ; Enable I/O node 2

// Connector J6, General Purpose I/O Registers
M7000->Y:$078802,0,8,U          ; 1st set of Outputs, 8-bit word
M7020->Y:$078800,0,8,U          ; 1st set of Inputs, 8-bit word
M7021->Y:$078801,0,8,U          ; 2nd set of Inputs, 8-bit word
// Connector J7, Expanded General Purpose I/O Registers
M7018->Y:$078805,0,8,U          ; 2nd set of Outputs, 8-bit word
M7022->Y:$078803,0,8,U          ; 3rd set of Inputs, 8-bit word
M7023->Y:$078804,0,8,U          ; 4th set of Inputs, 8-bit word
// I/O Node2 Registers
M7017->X:$78421,8,8,U           ; Middle Byte of I/O Node2's 1st 16-bit
M7019->X:$78421,16,8,U          ; High Byte of I/O Node2's 1st 16-bit
M7024->X:$78422,8,16,U          ; 2nd 16-bit register
M7025->X:$78423,8,16,U          ; 3rd 16-bit register

// This PLC Copies the Inputs to local I/O Gate, and sends the Outputs to Macro Gate
Open plc 1 clear
M7000=M7017                     ; Copy J6 Outputs to middle byte 1st 16-bit register
M7018=M7019                     ; Copy J6 Outputs to High byte 1st 16-bit register
M7024=M7020+M7021*256           ; Assemble J6 Inputs in 2nd 16-bit register
M7025=M7022+M7023*256           ; Assemble J7 Inputs in 3rd 16-bit register
Close
```

Master Ring Controller I/O Setup Example

```
End Gat
Del Gat
Close
I5=I5|2                ; Allow background PLC's
I6841=I6841|$000004    ; Enable I/O node 2
M7000->Y:$10FE,8,16,U  ; Use open register to create Outputs image word
M7017->X:$78421,8,16,U ; Node 2, 1st 16-bit register

// This PLC copies the outputs to Macro I/O Gate
Open plc 1 clear
M7017=M7000
Close
//***********************USE THESE SUGGESTED M-VARIABLES**************************//
//**********************TO WRITE TO OUTPUTS / READ INPUTS*************************//

// Bitwise Outputs (J6)
M7001->Y:$10FE,8,1     ; Output 1
M7002->Y:$10FE,9,1     ; Output 2
M7003->Y:$10FE,10,1    ; Output 3
M7004->Y:$10FE,11,1    ; Output 4
M7005->Y:$10FE,12,1    ; Output 5
M7006->Y:$10FE,13,1    ; Output 6
M7007->Y:$10FE,14,1    ; Output 7
M7008->Y:$10FE,15,1    ; Output 8
// Bitwise Outputs (J7)
M7009->Y:$10FE,16,1    ; Output 9
M7010->Y:$10FE,17,1    ; Output 10
M7011->Y:$10FE,18,1    ; Output 11
M7012->Y:$10FE,19,1    ; Output 12
M7013->Y:$10FE,20,1    ; Output 13
M7014->Y:$10FE,21,1    ; Output 14
M7015->Y:$10FE,22,1    ; Output 15
M7016->Y:$10FE,23,1    ; Output 16

// Bitwise Inputs (J6)
M7018->X:$078422,8,1   ; Input 01 Data Line, J6 Pin 1
M7019->X:$078422,9,1   ; Input 02 Data Line, J6 Pin 20
M7020->X:$078422,10,1  ; Input 03 Data Line, J6 Pin 2
M7021->X:$078422,11,1  ; Input 04 Data Line, J6 Pin 21
M7022->X:$078422,12,1  ; Input 05 Data Line, J6 Pin 3
M7023->X:$078422,13,1  ; Input 06 Data Line, J6 Pin 22
M7024->X:$078422,14,1  ; Input 07 Data Line, J6 Pin 4
M7025->X:$078422,15,1  ; Input 08 Data Line, J6 Pin 23
M7026->X:$078422,16,1  ; Input 09 Data Line, J6 Pin 5
M7027->X:$078422,17,1  ; Input 10 Data Line, J6 Pin 24
M7028->X:$078422,18,1  ; Input 11 Data Line, J6 Pin 6
M7029->X:$078422,19,1  ; Input 12 Data Line, J6 Pin 25
M7030->X:$078422,20,1  ; Input 13 Data Line, J6 Pin 7
M7031->X:$078422,21,1  ; Input 14 Data Line, J6 Pin 26
M7032->X:$078422,22,1  ; Input 15 Data Line, J6 Pin 8
M7033->X:$078422,23,1  ; Input 16 Data Line, J6 Pin 27
// Bitwise Inputs (J7)
M7034->X:$078423,8,1   ; Input 17 Data Line, J7 Pin 1
M7035->X:$078423,9,1   ; Input 18 Data Line, J7 Pin 20
M7036->X:$078423,10,1  ; Input 19 Data Line, J7 Pin 2
M7037->X:$078423,11,1  ; Input 20 Data Line, J7 Pin 21
M7038->X:$078423,12,1  ; Input 21 Data Line, J7 Pin 3
M7039->X:$078423,13,1  ; Input 22 Data Line, J7 Pin 22
M7040->X:$078423,14,1  ; Input 23 Data Line, J7 Pin 4
M7041->X:$078423,15,1  ; Input 24 Data Line, J7 Pin 23
M7042->X:$078423,16,1  ; Input 25 Data Line, J7 Pin 5
M7043->X:$078423,17,1  ; Input 26 Data Line, J7 Pin 24
M7044->X:$078423,18,1  ; Input 27 Data Line, J7 Pin 6
M7045->X:$078423,19,1  ; Input 28 Data Line, J7 Pin 25
M7046->X:$078423,20,1  ; Input 29 Data Line, J7 Pin 7
M7047->X:$078423,21,1  ; Input 30 Data Line, J7 Pin 26
M7048->X:$078423,22,1  ; Input 31 Data Line, J7 Pin 8
M7049->X:$078423,23,1  ; Input 32 Data Line, J7 Pin 27
```

MACRO Limits & Flags, Homing

Ring Motors' Limits and Flags are automatically copied by the Firmware. They can be accessed from the Ring Controller using Suggested M-Variables.

Note

Overtravel limits should be disabled locally (Ixx24=$820001) in a Geo Brick Drive when it is a MACRO slave. They are enabled for the corresponding axes at the MACRO Ring Controller side.

```
// Macro IC 0 Node 0 Flag Registers
M150->X:$003440,0,24   ; Macro IC 0 Node 0 flag status
M151->Y:$003440,0,24   ; Macro IC 0 Node 0 flag command
M153->X:$003440,20,4   ; Macro IC 0 Node 0 TUVW flags
M154->Y:$003440,14,1   ; Macro IC 0 Node 0 amplifier enable
M155->X:$003440,15,1   ; Macro IC 0 Node 0 node/amplifier
M156->X:$003440,16,1   ; Macro IC 0 Node 0 home flag
M157->X:$003440,17,1   ; Macro IC 0 Node 0 positive limit
M158->X:$003440,18,1   ; Macro IC 0 Node 0 negative limit
M159->X:$003440,19,1   ; Macro IC 0 Node 0 user flag

// Macro IC 0 Node 1 Flag Registers
M250->X:$003441,0,24   ; Macro IC 0 Node 1 flag status register
M251->Y:$003441,0,24   ; Macro IC 0 Node 1 flag command register
M253->X:$003441,20,4   ; Macro IC 0 Node 1 TUVW flags
M254->Y:$003441,14,1   ; Macro IC 0 Node 1 amplifier enable flag
M255->X:$003441,15,1   ; Macro IC 0 Node 1 node/amplifier fault flag
M256->X:$003441,16,1   ; Macro IC 0 Node 1 home flag
M257->X:$003441,17,1   ; Macro IC 0 Node 1 positive limit flag
M258->X:$003441,18,1   ; Macro IC 0 Node 1 negative limit flag
M259->X:$003441,19,1   ; Macro IC 0 Node 1 user flag

// Macro IC 0 Node 4 Flag Registers
M350->X:$003444,0,24   ; Macro IC 0 Node 4 flag status register
M351->Y:$003444,0,24   ; Macro IC 0 Node 4 flag command register
M353->X:$003444,20,4   ; Macro IC 0 Node 4 TUVW flags
M354->Y:$003444,14,1   ; Macro IC 0 Node 4 amplifier enable flag
M355->X:$003444,15,1   ; Macro IC 0 Node 4 node/amplifier fault flag
M356->X:$003444,16,1   ; Macro IC 0 Node 4 home flag
M357->X:$003444,17,1   ; Macro IC 0 Node 4 positive limit flag
M358->X:$003444,18,1   ; Macro IC 0 Node 4 negative limit flag
M359->X:$003444,19,1   ; Macro IC 0 Node 4 user flag

// Macro IC 0 Node 5 Flag Registers
M450->X:$003445,0,24   ; Macro IC 0 Node 5 flag status register
M451->Y:$003445,0,24   ; Macro IC 0 Node 5 flag command register
M453->X:$003445,20,4   ; Macro IC 0 Node 5 TUVW flags
M454->Y:$003445,14,1   ; Macro IC 0 Node 5 amplifier enable flag
M455->X:$003445,15,1   ; Macro IC 0 Node 5 node/amplifier fault flag
M456->X:$003445,16,1   ; Macro IC 0 Node 5 home flag
M457->X:$003445,17,1   ; Macro IC 0 Node 5 positive limit flag
M458->X:$003445,18,1   ; Macro IC 0 Node 5 negative limit flag
M459->X:$003445,19,1   ; Macro IC 0 Node 5 user flag

// Macro IC 0 Node 8 Flag Registers
M550->X:$003448,0,24   ; Macro IC 0 Node 8 flag status register
M551->Y:$003448,0,24   ; Macro IC 0 Node 8 flag command register
M553->X:$003448,20,4   ; Macro IC 0 Node 8 TUVW flags
M554->Y:$003448,14,1   ; Macro IC 0 Node 8 amplifier enable flag
M555->X:$003448,15,1   ; Macro IC 0 Node 8 node/amplifier fault flag
M556->X:$003448,16,1   ; Macro IC 0 Node 8 home flag
M557->X:$003448,17,1   ; Macro IC 0 Node 8 positive limit flag
M558->X:$003448,18,1   ; Macro IC 0 Node 8 negative limit flag
M559->X:$003448,19,1   ; Macro IC 0 Node 8 user flag

// Macro IC 0 Node 9 Flag Registers
```

```
M650->X:$003449,0,24   ; Macro IC 0 Node 9 flag status register
M651->Y:$003449,0,24   ; Macro IC 0 Node 9 flag command register
M653->X:$003449,20,4   ; Macro IC 0 Node 9 TUVW flags
M654->Y:$003449,14,1   ; Macro IC 0 Node 9 amplifier enable flag
M655->X:$003449,15,1   ; Macro IC 0 Node 9 node/amplifier fault flag
M656->X:$003449,16,1   ; Macro IC 0 Node 9 home flag
M657->X:$003449,17,1   ; Macro IC 0 Node 9 positive limit flag
M658->X:$003449,18,1   ; Macro IC 0 Node 9 negative limit flag
M659->X:$003449,19,1   ; Macro IC 0 Node 9 user flag
// Macro IC 0 Node 12 Flag Registers
M750->X:$00344C,0,24   ; Macro IC 0 Node 12 flag status register
M751->Y:$00344C,0,24   ; Macro IC 0 Node 12 flag command register
M753->X:$00344C,20,4   ; Macro IC 0 Node 12 TUVW flags
M754->Y:$00344C,14,1   ; Macro IC 0 Node 12 amplifier enable flag
M755->X:$00344C,15,1   ; Macro IC 0 Node 12 node/amplifier fault flag
M756->X:$00344C,16,1   ; Macro IC 0 Node 12 home flag
M757->X:$00344C,17,1   ; Macro IC 0 Node 12 positive limit flag
M758->X:$00344C,18,1   ; Macro IC 0 Node 12 negative limit flag
M759->X:$00344C,19,1   ; Macro IC 0 Node 12 user flag

// Macro IC 0 Node 13 Flag Registers
M850->X:$00344D,0,24   ; Macro IC 0 Node 13 flag status register
M851->Y:$00344D,0,24   ; Macro IC 0 Node 13 flag command register
M853->X:$00344D,20,4   ; Macro IC 0 Node 13 TUVW flags
M854->Y:$00344D,14,1   ; Macro IC 0 Node 13 amplifier enable flag
M855->X:$00344D,15,1   ; Macro IC 0 Node 13 node/amplifier fault flag
M856->X:$00344D,16,1   ; Macro IC 0 Node 13 home flag
M857->X:$00344D,17,1   ; Macro IC 0 Node 13 positive limit flag
M858->X:$00344D,18,1   ; Macro IC 0 Node 13 negative limit flag
M859->X:$00344D,19,1   ; Macro IC 0 Node 13 user flag
```

Ring Motors' homing setup is done similarly to homing with any Turbo PMAC. The Servo IC m Channel n capture control (I7mn2) and Servo IC m Channel n capture flag select control (I7mn3) have to be configured on the Slave Station. This can be done on the Macro Station with direct local communication or using MX commands from the master.

In a two 8-axis Brick Macro ring, configure Motor #9 to home to User Flag High. Motor #9 corresponds to Motor#1 on the Slave Station or Servo IC 0 channel 1:

```
MX0, I7012= 2  ; Servo IC 0 Channel 1Capture Control (flag high)
MX0, I7013= 3  ; Servo IC 0 Channel 1Capture Flag Select Control (user flag)
```

In a two 8-axis Brick Macro ring, configure Motor #14 to home to User Flag High. Motor #14 corresponds to Motor#6 on the Slave Station or Servo IC 1 channel 2:

```
MX0, I7122= 2  ; Servo IC 1 Channel 2 Capture Control (flag high)
MX0, I7123= 3  ; Servo IC 1 Channel 2 Capture Flag Select Control (user flag)
```

Note

Issuing a #n Home from the Master Ring Controller will initiate the home move on the corresponding motor #n

Absolute Position Reporting Over MACRO

The Geo Brick family supports a wide variety of absolute encoders. When used as a MACRO slave, the simplest way to report the absolute position to the master (ring controller) is to use the MACRO auxiliary communication (read/write). **Example:** Retrieving motor #9's absolute position on power-up from motor #1 on a slave Brick with MACRO yields the online command: **MXR0,M162,M962** which could be ultimately inserted in an initialization PLC.

DRIVE STRUCTURE AND TROUBLESHOOTING

The Geo Brick Drive is a multilayer of digital and power electronic boards:

Add-in Board (603910)

PMAC Control Board (603793)

Amplifiers (603800, 603803)

Geo Brick Drive

The optional add-in board comprises primarily of:

- Non-standard (quadrature) feedback processing circuitry (i.e. sinusoidal, serial)
- Additional analog inputs, analog output, handwheel port
- MACRO interface

The PMAC control board comprises primarily of:

- Turbo PMAC2 Controller (trajectory generation, multi-task processing)
- Limits, Flags, general purpose inputs/outputs...etc
- Primary Communication (i.e. USB, Ethernet, RS232)
- High resolution 16-bit analog inputs

The amplifier board(s) comprise primarily of:

- Amplifier controls processors
- Power electronic blocks (i.e. IGBT, capacitors, current sensors)
- Amplifier safety electronics hardware (i.e. soft start, over current, over temperature)

Default Mode, Strobe Word (I7m06) Setting

In this mode, the Geo Brick amplifier block returns phases A and B current feedback as well as global and axis faults to the Controls Section. The ADC Strobe Word in this mode has to be set (saved) to $3FFFFF.

Caution

The ADC Strobe Word (I7m06) has been masked, in PMAC firmware version 1.944 and above, to avoid bad user settings and drive damage. The Geo Brick Drive will reject wrong settings automatically.

Note

The Geo Brick Drive ADC Strobe word has to be set to $3FFFFF for each Servo IC, with motors attached to it, in normal mode operation.

Enhanced Mode (Reading IGBT Temperature and Bus Voltage)

Enhanced mode enables the controls section (thus the user) to access information on the amplifier side normally not available directly to the user, information such as IGBT temperature and Bus Voltage.

	Global Faults	Axis Faults	IGBT Temperature	Bus Voltage
Default Mode	√	√	N/A	N/A
Enhanced Mode	√	√	√	√

This information can be useful to display on the operator interface, and troubleshooting exercises. The ADC strobe word has to be set properly for either IGBT or Bus Voltage reading. Remember that the Global and Axis faults are returned by default, and are always available.

	Default	IGBT Temperature	Bus Voltage
ADC Strobe Word	$3FFFFF	$300FFF	$301FFF

The IGBT Temperature, Bus Voltage, Axis and Global faults data can be retrieved from ADC phases A, and B of each axis. The information consists of 8 bits of data located in bits 4 through 11.

Axis #	ADC A	ADC B
1	Y:$078005	Y:$078006
2	Y:$07800D	Y:$07800E
3	Y:$078015	Y:$078016
4	Y:$07801D	Y:$07801E
5	Y:$078105	Y:$078106
6	Y:$07810D	Y:$07810E
7	Y:$078115	Y:$078116
8	Y:$07811D	Y:$07811E

Phase ADC A returns Global and Axis Faults (in both default and enhanced modes):

ADC A																							
23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
												Global and Axis Faults											

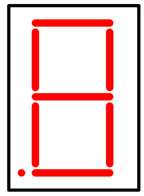
See complete list of errors and description in following section, Global and Axis Faults, Error Codes.

Phase ADC B returns IGBT, and Bus voltage readings (only in Enhanced mode settings):

ADC B																							
23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
												IGBT and BUS Voltage											

See IGBT Temperature, and Bus Voltage reading description in subsequent section, reading IGBT temperature and Bus voltage.

Error Codes, Global And Axis Faults



D1: AMP Status. The Global and Axis faults are interpreted by the Amplifier processor(s) and sent to the 7-segment 3-character scrolling display (D1). The scrolling display begins with a number indicating the faulted axis number (1-8) or the letter A–indicating a Global Fault, followed by the letter F–indicating a fault, followed by the specific Fault Code. The blinking dot is the heartbeat of the Amplifier processor(s) and is always active in normal mode operation. It is turned off or not blinking when the master processor is in reset mode to reload firmware or has no logic power (hardware failure). The display is blank if there are no axes enabled, and no faults.

7-SEGMENT DISPLAY	BIT CODE	DESCRIPTION
		AXIS FAULTS (n = 1-8 for Axis Number)
nF1	$01	**Axis-n Peak Current Fault:** Indicates that a current output greater than the amplifier peak current specification (but less than the short circuit nF3 threshold) has been detected and sustained for about 10 milliseconds.
nF2	$02	**Axis-n RMS Current Fault:** Indicates that the amplifier I2T model, hard-coded in the amplifier processor projecting current output over time, has been violated within the operating current specification range of the amplifier. Over-sized motor?
nF3	$03	**Axis-n Short Circuit Fault:** Indicates that the short circuit current output threshold (twice the rated peak current) has been exceeded (fast acting very high current output) and sustained for about 10 microseconds. Check motor wiring for shorts. Unplug motor cable and recycle power (strongly advised).
nF5	$05	**Power Stage (IGBT) Over-Temperature Fault:** Indicates excessive IGBT temperature has been detected. Power off the drive and let it cool down. Check cabinet ventilation, and fan functionality.
0	$FF	**Axis-n Enabled:** Normal mode operation, one or more axes enabled.
		GLOBAL FAULTS
AF1	$04	**PWM Over Frequency Fault:** Indicates that the PWM has exceeded the specified limit. This can occur if clock settings are incorrect, or bus voltage is not present.
AF3	$0D	**EEPROM Communication Fault:** Indicates that the memory has been corrupted.
AF4	$0E	**Shunt RMS Fault:** Indicates that the shunt resistor turn-on time has exceeded the permissible time of 2 seconds. Make sure the Bus Input is within spec.
AFb	$07	**Bus Input Over Voltage Fault:** Indicates that either excessive bus voltage has been detected, or bus voltage is not present. Make sure a shunt resistor is installed.
AFd	$09	**Shunt resistor Short Circuit Fault:** Indicates that a short has been detected at the Shunt resistor circuitry.
AFL	$0C	**No Bus Input Voltage Fault:** Indicates that the AC Bus Input is lost or has dropped below the minimum threshold (87 VAC).
U		EPROM Corrupted

Reading IGBT Temperature And Bus Voltage

IGBT Temperature reading:

The baseline IGBT temperature is set at 25°C (77°F), with ADC bits [11-4] value of $21 (Hexadecimal). Above the baseline temperature, every additional 2.13°C (35.834°F) correspond to $1 hexadecimal ADC count. The maximum IGBT temperature for the Geo Brick Drive is about 125°C (257°F), or $5B Hexadecimal ADC counts.

Bus Voltage reading:

Every ADC $1 Hexadecimal count corresponds to 5.875 Volts DC. See electrical specifications for over-voltage, shunt resistor turn-on,

The following, is an example PLC that updates the DC Bus Voltage (converted to AC) every 3 seconds, and Axis-1 IGBT temperature in degree Celsius every 30 seconds:

```
End Gat
Del Gat
Close

// Substitutions and definitions
#define IC0StrobeWord         I7006   ; Servo IC#0 ADC Strobe Word
#define Mtr1ADCB              M7050   ; Motor 1 ADC Phase B
#define ACBusVoltage          M7051   ;
#define LastIC0Strobe         P7050   ;
#define CS1Timer1             I5111   ; Coordinate System &10 Countdown Timer 1
#define CS1Timer2             I5112   ; Coordinate System &10 Countdown Timer 2
#define IGBTAxis1Temp         M7054   ;
#define BaselineTemp          P7052   ;
#define TempConstant          P7053   ;
#define AmbientTemp           P7054   ;

Mtr1ADCB->Y:$78006,4,8        ; Channel 1 ADC Phase B
ACBusVoltage->*               ; Self-referenced M-variable to store Bus Voltage reading
IGBTAxis1Temp->*              ; Self-referenced M-variable to store IGBT Temperature reading
LastIC0Strobe= 0              ; 0 at download
IGBTAxis1Temp= 0              ; 0 at download
BaselineTemp= 33              ; $21 at 25 Degree Celsius
TempConstant= 2.13            ; 2.13 Degrees C for each additional Hex Count
AmbientTemp= 25               ; Ambient at 25 degrees Celsius

// This PLC example updates AC Bus Voltage reading (M7051) every 3 seconds and
// Axis-1 IGBT Temperature reading (M7054) in degree Celsius every 30 seconds
Open plc 1 clear
If (CS1Timer2<0)              ; Read IGBT Temperature
 IC0StrobeWord = $300FFF      ; Set Strobe Word for Enhanced Mode, IGBT Temperature
 CS1Timer2=50*8388608/I10 While(CS1Timer2>0) Endw ; 50 msec Delay
 IGBTAxis1Temp=(Mtr1ADCB-BaselineTemp)* TempConstant+ AmbientTemp
 CS1Timer2=30000*8388608/I10  ; 30 sec IGBT Temperature Update
EndIF
// AC Bus Voltage (M7051)
If (LastIC0Strobe != IC0StrobeWord)
        IC0StrobeWord = $301FFF; Set ADC Strobe Word for Enhanced Mode, Bus Voltage
        LastIC0Strobe = IC0StrobeWord
        CS1Timer1= 50*8388608/I10 While(CS1Timer1>0) Endw ; 50 msec Delay
EndIf
ACBusVoltage=(Mtr1ADCB*5.875)/sqrt(2)                       ; Convert to AC
CS1Timer1= 3000*8388608/I10 While(CS1Timer1>0) Endw  ; 3 sec Bus Voltage update
Close
```

Note

Toggling the ADC Strobe Word at a very fast rate is not desirable. Handshaking between the PMAC and the amplifier processor may take to up to 50 milliseconds.

Calculating Motor Current Output Example

Channel 1 on a 5/10A Geo Brick Drive is driving a commutated brushless motor. The instantaneous current output can be calculated as follows:

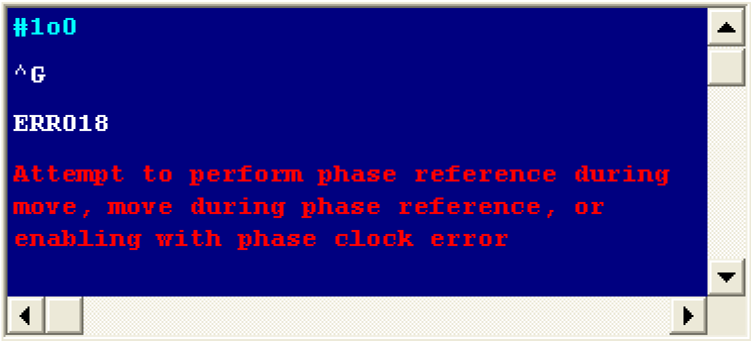
```
// Substitutions and definitions
#define MaxADC                P7055   ; Max ADC reading. See electrical specifications
#define MaxOutput             P7056   ; Maximum Command Output
#define Mtr1ActQuadCurrent    M175    ; Motor 1 Actual Quadrature Current
#define Mtr1ActDirectCurrent  M176    ; Motor 1 Actual Direct Current
#define GlobalVar1            P7057   ; General Purpose Global Variable 1
#define GlobalVar2            P7058   ; General Purpose Global Variable 2
#define Axis1CurrentOutput    P7059   ; User variable to store Axis-1 current

Mtr1ActQuadCurrent->X:$0000B9,8,16,S         ; #1 Actual quadrature current (Suggested M-var)
Mtr1ActDirectCurrent->Y:$0000B9,8,16,S       ; #1 Actual direct current (Suggested M-var)

MaxADC= 16.26                                ; = 16.26 for 5/10A    -User Input
                                             ; = 26.02 for 8/16A
                                             ; = 48.08 for 15/30A

MaxOutput=32767*0.866                ; 32767 * sqrt(3)/2

// This PLC returns Axis-1 instantaneous current output (P7059) in Amps
Open Plc 1 Clear
// Quad^2 + Direct^2
GlobalVar1=(Mtr1ActQuadCurrent*Mtr1ActQuadCurrent)+(Mtr1ActDirectCurrent*Mtr1ActDirectCurrent)
// Get SQRT
GlobalVar2=exp(0.5*ln(GlobalVar1))
// Convert to Current. Assume most efficient bus voltage
Axis1CurrentOutput=MaxADC*GlobalVar2/(MaxOutput*1.414)
Close
```

LED Status

Symbol	Function(s)	State	Light	Description
RLY X9	Axis#5 Status Brake/Relay#5 Status	**On** Off	**Green** Unlit	Green when Axis#5 Enabled or Brake/Relay#5 output is true
RLY X10	Axis#6 Status Brake/Relay#6 Status	**On** Off	**Green** Unlit	Green when Axis#6 Enabled or Brake/Relay#6 output is true
RLY X11	Axis#3 Status Brake/Relay#3 Status	**On** Off	**Green** Unlit	Green when Axis#3 Enabled or Brake/Relay#3 output is true
RLY X12	Axis#4 Status Brake/Relay#4 Status	**On** Off	**Green** Unlit	Green when Axis#4 Enabled or Brake/Relay#4 output is true
+5V	+5V Logic Power	**On** Off	**Green** Unlit	Green indicates good +5V controller power. Normal mode operation.
WD	Watchdog	**On** Off	**Red** Unlit	Red when watchdog has tripped. Unlit is normal mode operation.
Active	Abort Status	**On** Off	**Red** Unlit	Red when +24V is disconnected (ABORT is true)
Inactive	Abort Status	**On** Off	**Green** Unlit	Green when +24V is applied (ABORT is not true, Normal mode operation)
BUS	Bus Voltage	**On** Off	**Red** Unlit	Red indicates Bus Power is applied or residual

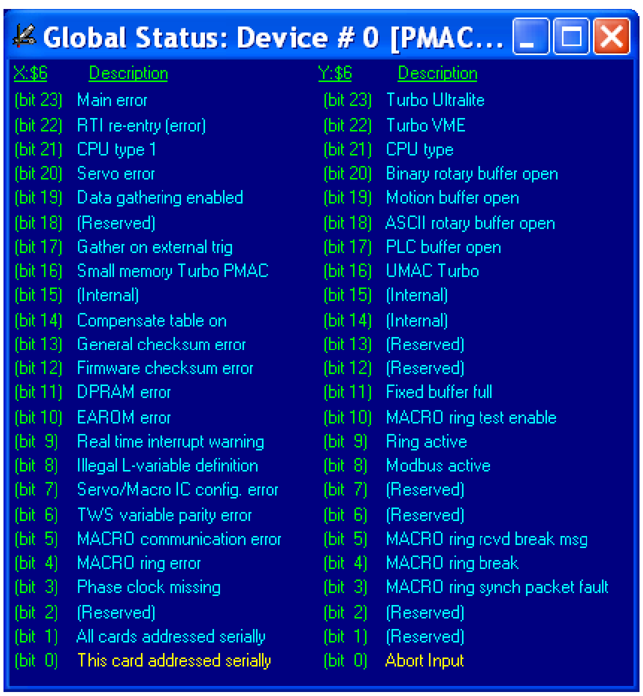
Error 18 (Erro18)

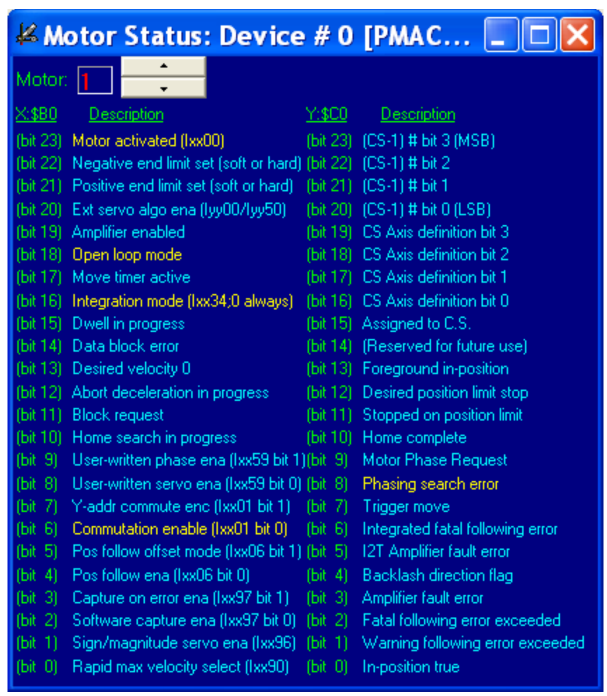
Error 18 “Attempt to perform phase reference during move, move during phase reference, or enabling with phase clock error” is highlighted in red in the terminal window:



This error occurs if any of the following is true:

- The addressed motor is not phased.
  In this mode, the phasing search error bit is highlighted in the Motor Status window.
- No Phase Clock (internal).
  In this mode, the Phase Clock Missing bit is highlighted in the Global Status window.
- +24V Abort not applied.
  In this mode, the Abort Input bit is highlighted in the Global Status window.





Watchdog Timer Trip

On a Geo Brick Drive, the watchdog timer trigger illuminates the red WD LED and interrupts communication. It occurs if any of the following is true:

- PMAC CPU over-clocked
  In this mode, the CPU signals that is has been overloaded with computation and cannot accomplish tasks in a timely manner. i.e. bad programming such as an infinite loop, or too much computation (Kinematics) requiring faster CPU option.

- Wrong clock settings
  In this mode, the user has downloaded or written bad values to clock setting parameters.

- Hardware +5V failure (internal)
  In this mode, the internal 5V logic circuitry has failed. Check 5V Led Status.

- Downloading wrong configuration file (I4900)
  In this mode, the user has reloaded a configuration file uploaded from a 4-axis unit (Servo IC 1 parameters set to zero) into an 8-axis unit, thus writing zero to the second Servo IC clock parameters. Commenting out variables I7100…7106 (or forcing then to hold the same values as I7000…I7106) eliminates the watchdog problem.

Geo Brick Drive Specific Online Commands

Type

Function: Report type of Turbo PMAC
Scope: Global
Syntax: **TYPE**
TYP

Caution

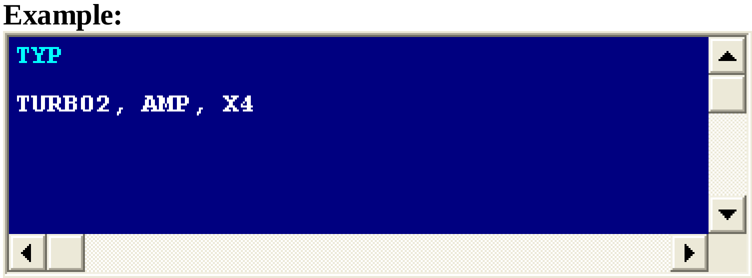
A Geo Brick Drive is malfunctioning or damaged hence unsafe to use, and may result in equipment damage if AMP is not reported in the **TYPE** command (TURBO2, X4)

This command causes Turbo PMAC to return a string reporting the configuration of the board(s). Although this is a general Turbo PMAC online command, it will report a unique configuration for Geo Brick Drives as a text string in the format

TURBO2, AMP, Xn

Where:
TURBO2 indicates that the controller is a Turbo PMAC2, AMP indicates the presence of a Geo Brick Amplifier, Xn is the multiplication of crystal frequency to CPU frequency (20 MHz).

Example:



X4 value reporting 80 MHz CPU operation.

Ampversion

Function: Report Amplifier Processor Firmware Version Number
Scope: Global
Syntax: **AMPVERSION**
AMPVER

Caution

The **AMPVER** command will kill all enabled motors, which can be hazardous in some systems (i.e. enabled vertical axis without an automatic software or hardware braking mechanism)

This command causes the Geo Brick Drive to report the firmware version of the amplifier processor. The response is a 6-digit hex value. The information reported in the amplifier version number is mostly for internal use, and technical support troubleshooting.

Example:

```
AMPVER

$010301
```

Ampmod

Function: Report Geo Brick Drive Part Number
Scope: Global
Syntax: **AMPMOD**

Caution

The **AMPMOD** command will kill all enabled motors, which can be hazardous in some systems (i.e. enabled vertical axis without an automatic software or hardware braking mechanism)

This command causes the Geo Brick Drive to report the part number. The response is an ASCII numeric, and should match the part number on the side label/inspection tag of the unit. It can be decoded using the part number table.

Example:

```
AMPMOD

GBL4-C0-802-10S
```

Ampsid

Function: Report Serial Electronic Identification Number
Scope: Global
Syntax: **AMPSID**

Caution

The **AMPSID** command will kill all enabled motors, which can be hazardous in some systems (i.e. enabled vertical axis without an automatic software or hardware braking mechanism)

This command causes the Geo Brick Drive to report the electronic identification number of the amplifier module. The information reported in the identification number is a 16-digit ASCII string dedicated for internal use, and technical support troubleshooting.

Example:

Ampclrf

Function: Amplifier Clear Fault(s)
Scope: Global
Syntax: **AMPCLRF**

Caution

The **AMPCLRF** command will enable then kill all the motors to clear faults. If **AMPCLRF** is issued with no existing errors, all previously enabled motors will be killed, which can be hazardous in some systems (i.e. enabled vertical axis without an automatic software or hardware braking mechanism)

This command will clear amplifier faults in the Geo Brick Drive. The **AMPCLRF** is typically used to clear global faults (scrolling fault display starting with an A) rather than axis individual faults (scrolling fault display starting with an n, where n =1-8 for axis number). Remember, individual axis fault(s) in the Geo Brick Drive can be cleared by enabling the axis, most simply done by issuing a zero percent open loop command (#nO0) output then killing (#nK) the motor right after if necessary.

Note

The **AMPCLRF** command is available with PMAC firmware version 1.946 or newer.

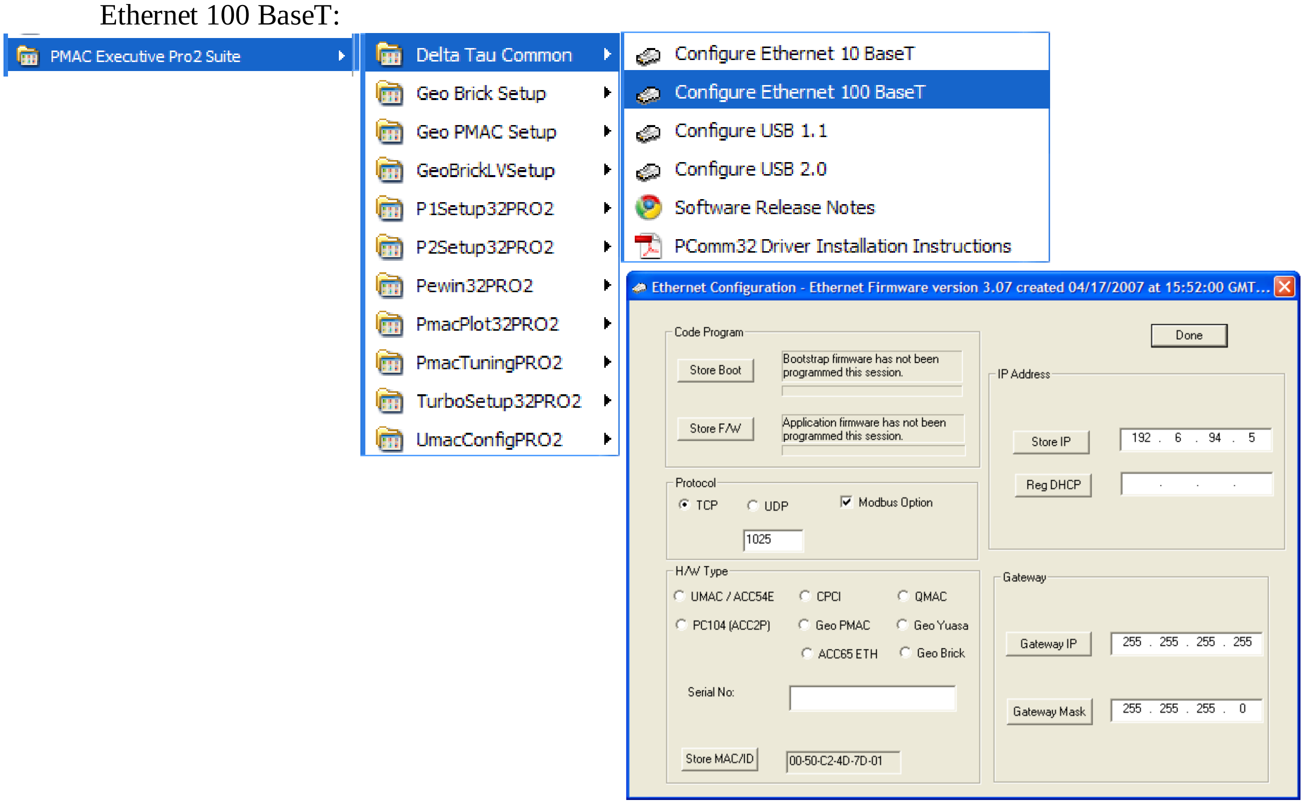
Boot Switch SW (Firmware Reload) – Write-Protect Disable

This momentary button switch has two essential functions:

1. Putting the Geo Brick Drive in Boostrap Mode for reloading PMAC firmware.

2. Disabling the USB/Ethernet communication write-protection for
   - Changing IP address, Gateway IP or MASK
   - Enabling ModBus
   - Reloading communication boot and firmware

   These functions are accessible through the Configure Ethernet 100 BaseT utility found in the Windows Start menu under PMAC Executive Pro2 Suite > Delta Tau Common > Configure Ethernet 100 BaseT:



Note

- This utility only works with USB communication.
- The Pewin32Pro2 or any other software communicating to the Brick must be closed before launching this utility.

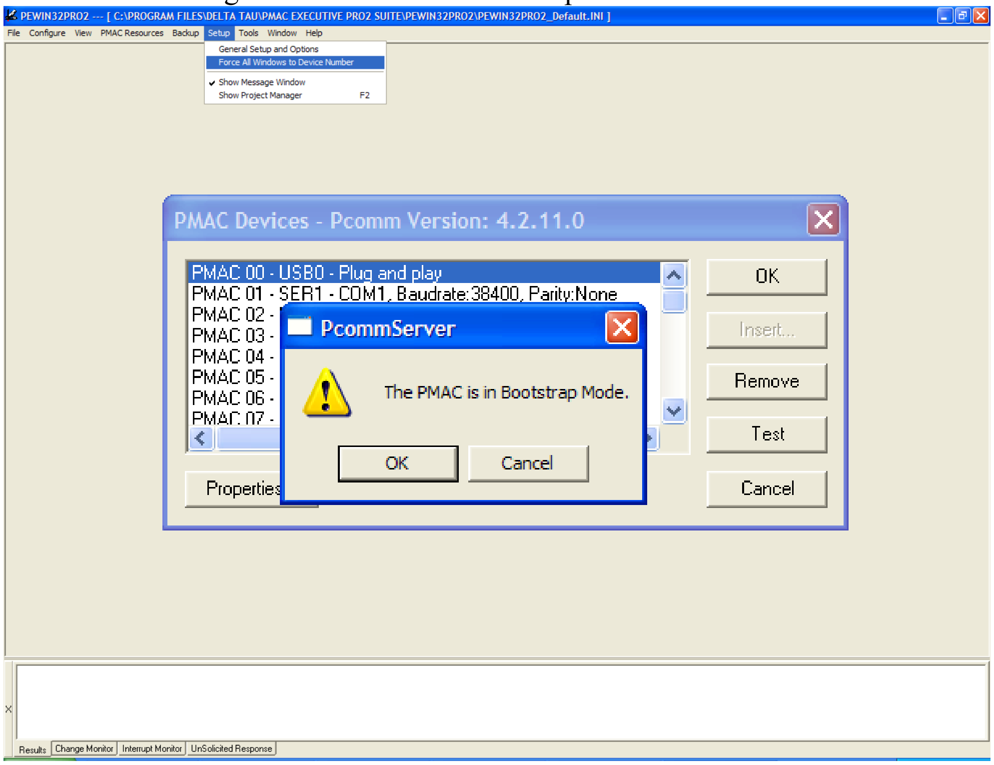
Reloading PMAC firmware

The following steps ensure proper firmware reload/upgrade.

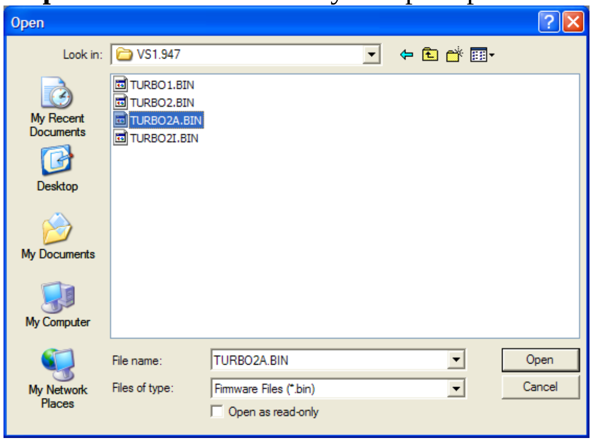
Step1: Power up the unit while holding the BOOT SW switch down.

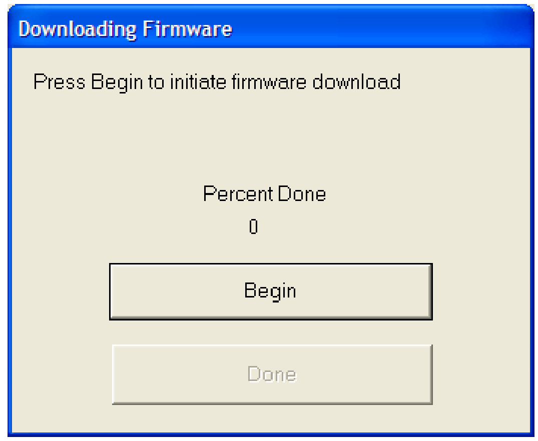
Step2: Release the BOOT SW switch approximately 2-3 seconds after power-up.

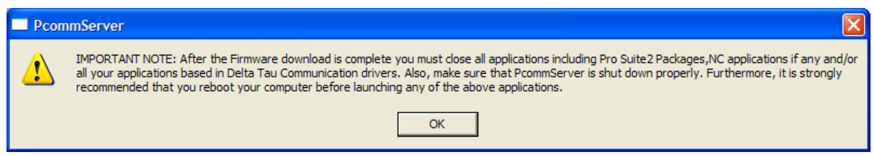
Step3: Launch the Pewin32Pro2.
Run the PMAC Devices window under Setup > Force All Windows To Device Number.
Click Test for the corresponding communication method.
Click ok for message "The PMAC is in Boostrap Mode"



Step4: The download utility will prompt for a .BIN file. MAKE SURE you open the correct file.



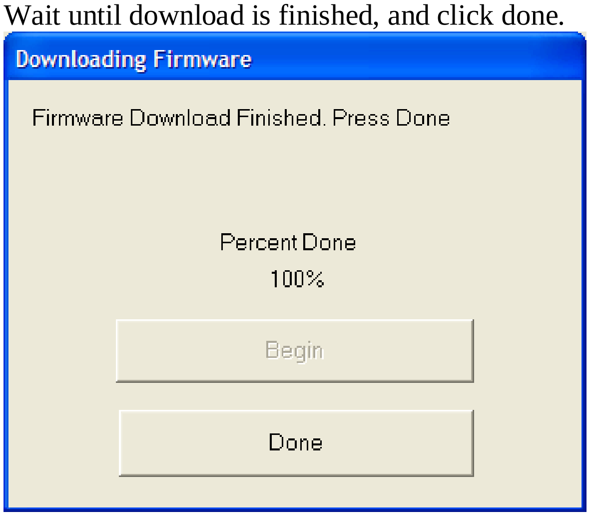




Note

The PMAC firmware file for Geo Brick Drives MUST ALWAYS be TURBO2**A**.BIN.

Step4: Wait until download is finished, and click done.



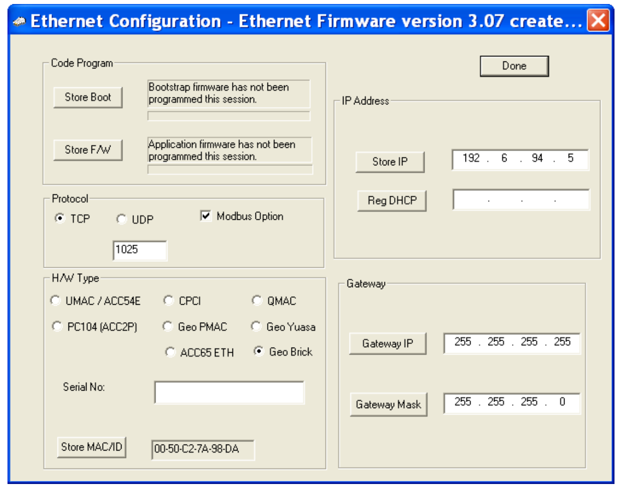
Step5: Close all PMAC applications (i.e. Pewin32Pro2), and recycle power.

Changing IP Address, Gateway IP, Or Gateway Mask

In order to change any of these addresses, the BOOT SW switch has to be held down prior to pressing the corresponding Store button. The following steps ensure proper configuration:

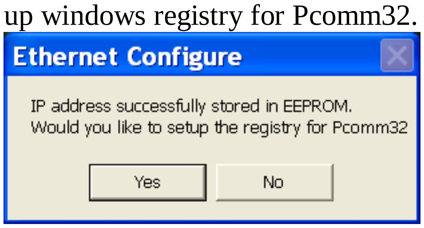
Step1: Change the desired address field
Step2: Hold the BOOT SW switch down
Step3: Press on the corresponding Store button

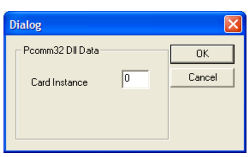
- Store IP for changing IP address
- Gateway IP for changing Gateway IP
- Gateway Mask for changing Gateway Mask

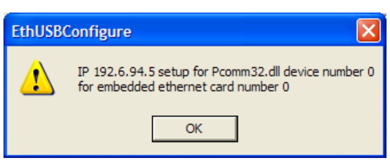


Step4: Release the BOOT SW switch after the corresponding confirmation message is received:

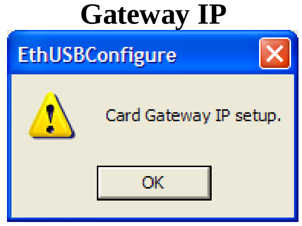
For changing the **IP address**, follow through the subsequent messages for setting up windows registry for Pcomm32.



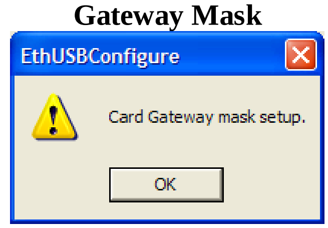




Gateway IP



Gateway Mask



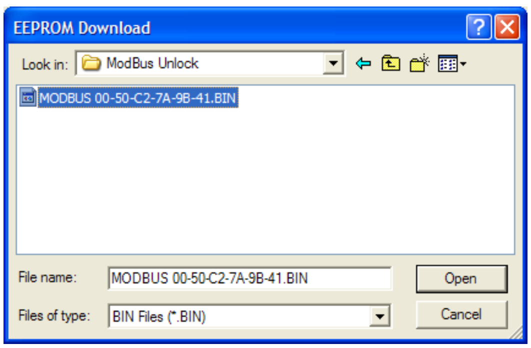
Step5: Click Done, and recycle logic power (24V) on the Brick

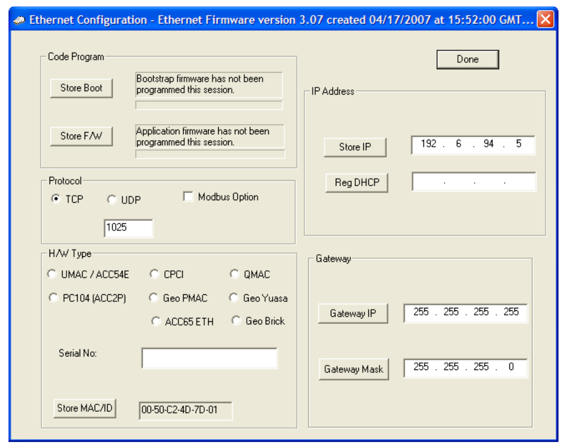
Enabling ModBus

A Brick unit ordered initially with the ModBus option is normally enabled by factory.
However, ModBus is a field upgradeable option. The user needs to provide Delta Tau (or their local distributor) with the MAC ID of the Brick unit. This is found in the lower left hand side of the Ethernet 100 Base T utility. Upon purchase of the ModBus Option, a .BIN file is obtained from Delta Tau for this purpose. Installing this feature successfully requires the following procedure:

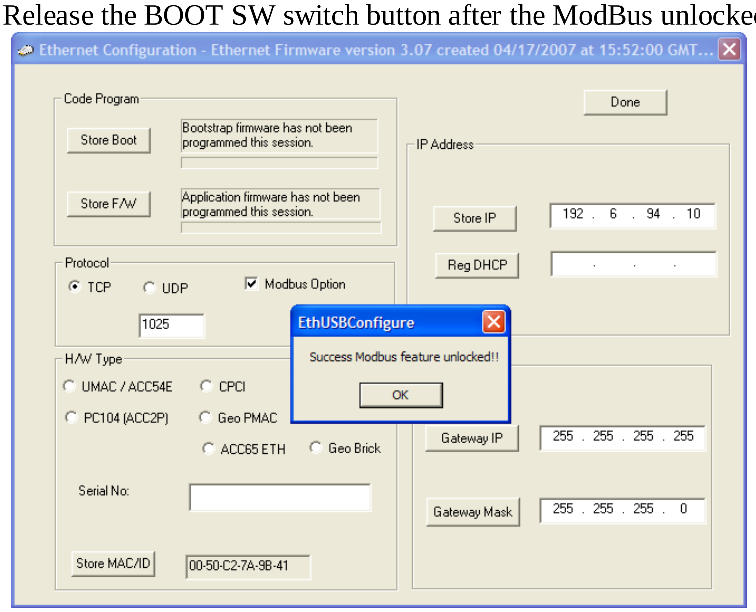
Step1: Hold the BOOT SW switch button down

Step2: Click on **ModBus Option.** The utility will prompt for the .bin file.
MAKE SURE you open the correct file.





Step3: Release the BOOT SW switch button after the ModBus unlocked message is generated.



Step4: Click Done, and recycle logic power (24V) on the Brick

Reloading Boot And Communication Firmware

The boot and firmware .IIC files are required for this procedure. They are normally obtained directly from Delta Tau, or downloaded from the PMAC forum Webpage. The following steps ensure proper configuration:

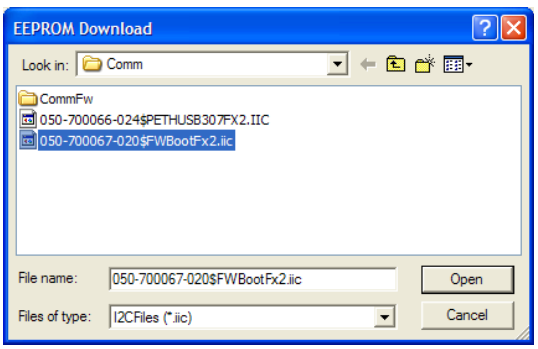
Caution

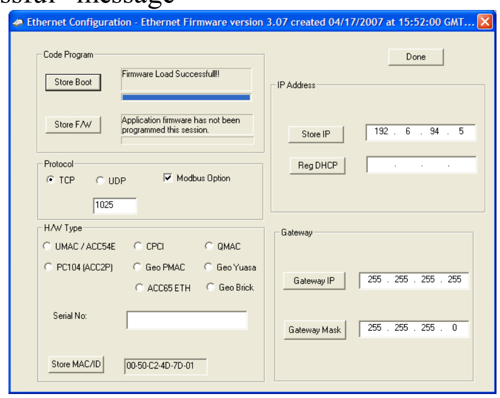
Downloading the wrong boot or communication files will severely corrupt the functionality of the communication processor.

Step1: Hold the BOOT SW switch down

Step2: Click on Store Boot

Step3: The utility will prompt for the boot file. MAKE SURE you open the correct .IIC file (ending with BootFx2.iic) and wait for "firmware load successful" message



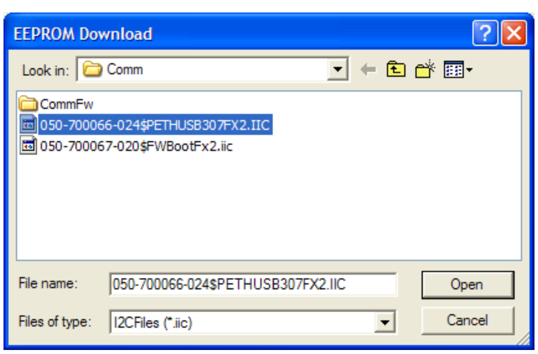


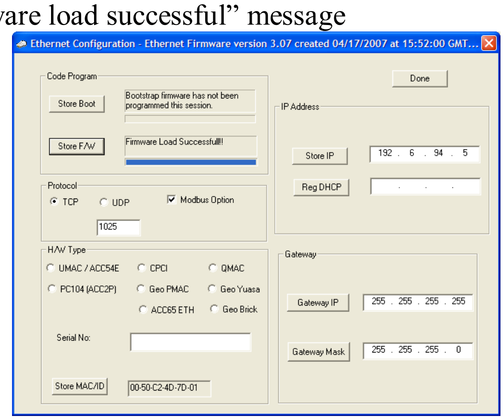
Step4: Click on Store F/W

Note

The BOOT SW switch button can be released temporarily (between file downloads). But it MUST to be held down the entire time the boot or firmware files are being written.

Step5: The utility will prompt for the Firmware file. MAKE SURE you open the correct .IIC file (ending with ETHUSB307FX2.iic) and wait for "firmware load successful" message





Step6: Release the BOOT SW switch. Click Done, and recycle logic power (24V) on the Brick.

Reset Switch SW (Factory Reset)

This momentary switch button is used to reset the Geo Brick Drive back to factory default settings, global reset.

Caution

Issuing a SAVE after power up (with the reset switch held down) will permanently erase any user configured parameters.

Reset SW instructions: Power down the unit then power back up while holding the Reset SW switch down. Release the Reset SW once the unit is powered up. The factory default parameters are now restored from the firmware EEPROM into the active memory. Issue a SAVE and a $$$ to maintain this configuration.

For traditional PMAC users, this switch is the equivalent of Jumper E51 on PC or standalone boards.

LIST OF CHANGES, UPDATES

This is a list of significant changes and user related updates:

AMPVER Command, December 2007

Caution

Failure to execute the AMPVER command on power-up for firmware 1.943 and earlier can result in equipment damage.

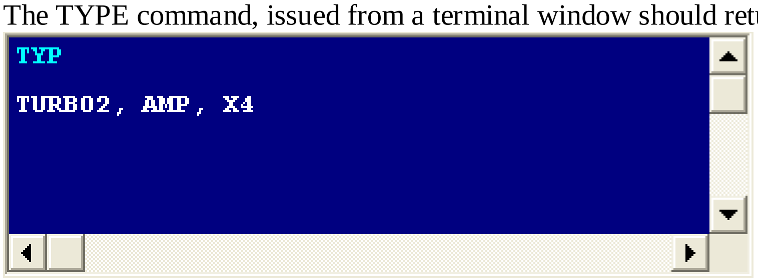
Geo Brick Drives, firmware version 1.943 and earlier, require a minimum delay of 500 milliseconds and the issuing of AMPVER command on power up. This will ensure establishing communication between the amplifier processor and the PMAC, thus conveying amplifier faults and status properly.

Example:

```
OPEN PLC 1 CLEAR
DIS PLCC 0..31          ; Disable all compiled PLCs
DIS PLC 0               ; Disable foreground PLC
DIS PLC 2..31           ; Disable background PLCs
I5111=500*8388608/I10  ; 500 ms delay using C.S1 countdown timer
WHILE(I5111>0)          ;
END WHILE               ;
CMD"AMPVER"             ;
I5111=20*8388608/I10   ; 20 ms delay using C.S1 countdown timer.
WHILE(I5111>0)          ; This provides enough time for the drive
END WHILE               ; to process the ampver command.
ENAPLC 2..31            ; Re-enable background PLCs
ENAPLC 0                ; Re-enable foreground PLC
ENA PLCC 0..31          ; Re-enable all compiled PLCs
DISABLE PLC 1           ; Disable PLC 1, run only once on power up or reset
CLOSE
```

Quick Verification:

The TYPE command, issued from a terminal window should return TURBO2, AMP, X4



This is the desired response. A response of TURBO2, X4 is not appropriate (the Drive should not be used in this case) and it implies that the PLC has not executed properly (i.e., I5 setting) and/or the AMPVER command has not been issued, or executed properly.

Note

Geo Brick Drives, with firmware version 1.944 and later do not require sending AMPVER command on power-up

External Encoder Power Supply Connector, April 2010

The introduction of special feedback devices (i.e. Sinusoidal, Serial, and Resolver) and MACRO Fieldbus connectivity onto the Geo Brick controller/drive series has amplified the 5-volt power budget significantly. For encoder power requirements exceeding 4 Amperes, an external 5-volt power supply must be used to drive the encoders. A new connector (+5V ENC PWR) is introduced to support this scheme.

Note

See +5V ENC PWR section for pin-out and wiring scheme.

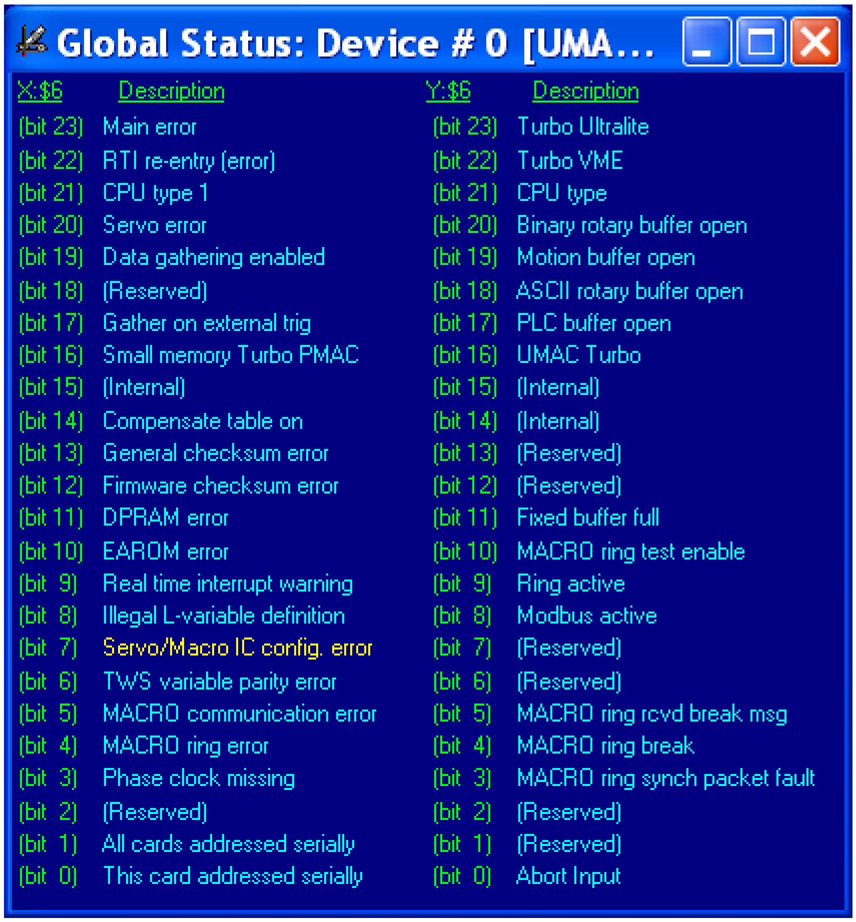
EEPROM Write-Protect Enable. April 2010

This change protects the Communication EEPROM from brown out conditions, causing the complete wipe out of the communication firmware. In normal mode operation, the EEPROM is now write-protected at all times. But in some cases, the write-protect function needs to be disabled. Such cases as:

- Changing the IP address, Gateway IP, And Gateway Mask
- Enabling ModBus
- Reloading Boot, and Communication firmware

AMPVER Fail-Safe Mechanism. Configuration Error, May 2010

In firmware version 1.947 and later, the Servo/Macro IC config. Error bit is set (highlighted) in the Global Status window if the **ampver** command has internally failed on power-up.
In this scenario, the PMAC does not recognize that it is connected to a Geo Brick power block, and the amplifier status is not reported properly making the application unsafe.
Motors are not allowed to be enabled in this mode. Recycling power on the Geo Brick Drive may clear the error, but generally the occurrence of a config. Error implies hardware malfunction/failure.



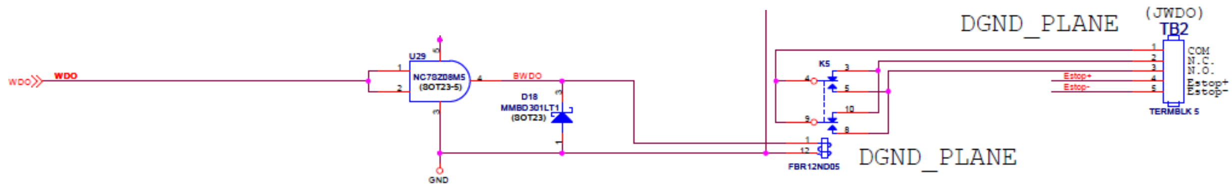
Note

In this mode, the **TYPE** command returns **TURBO2, X4** instead of **TURBO2, AMP, X4**

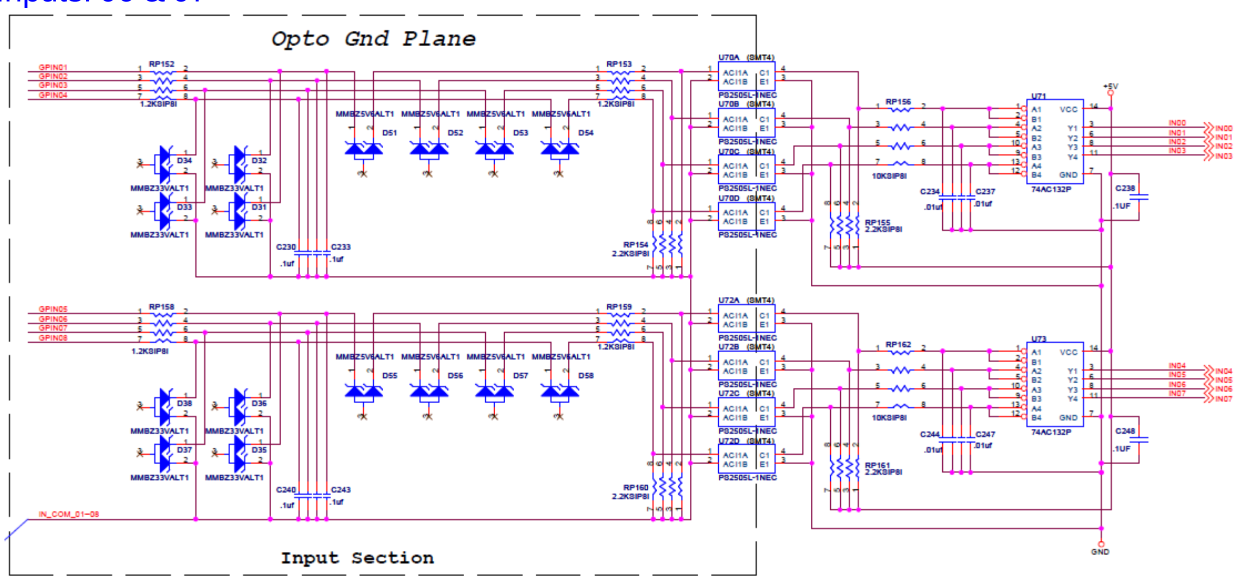
Appendix A:

Schematic Samples

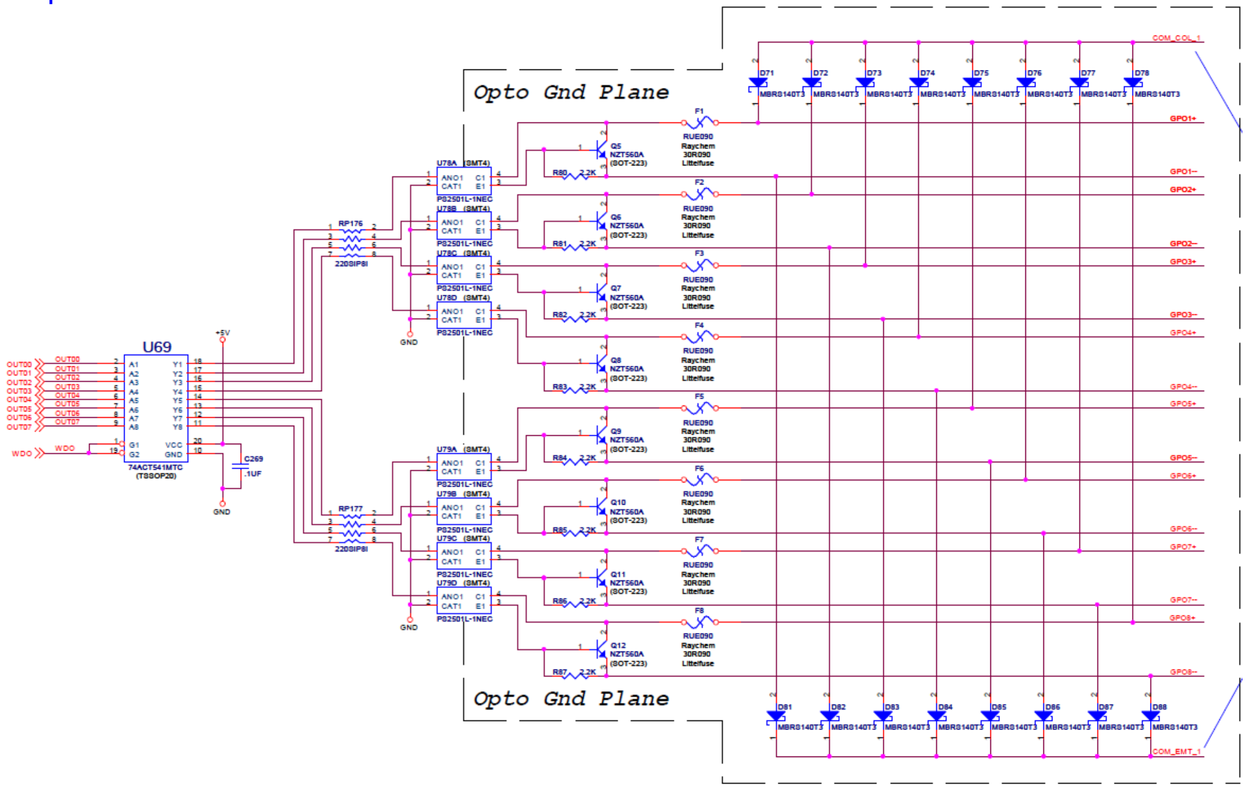
Watchdog: X15



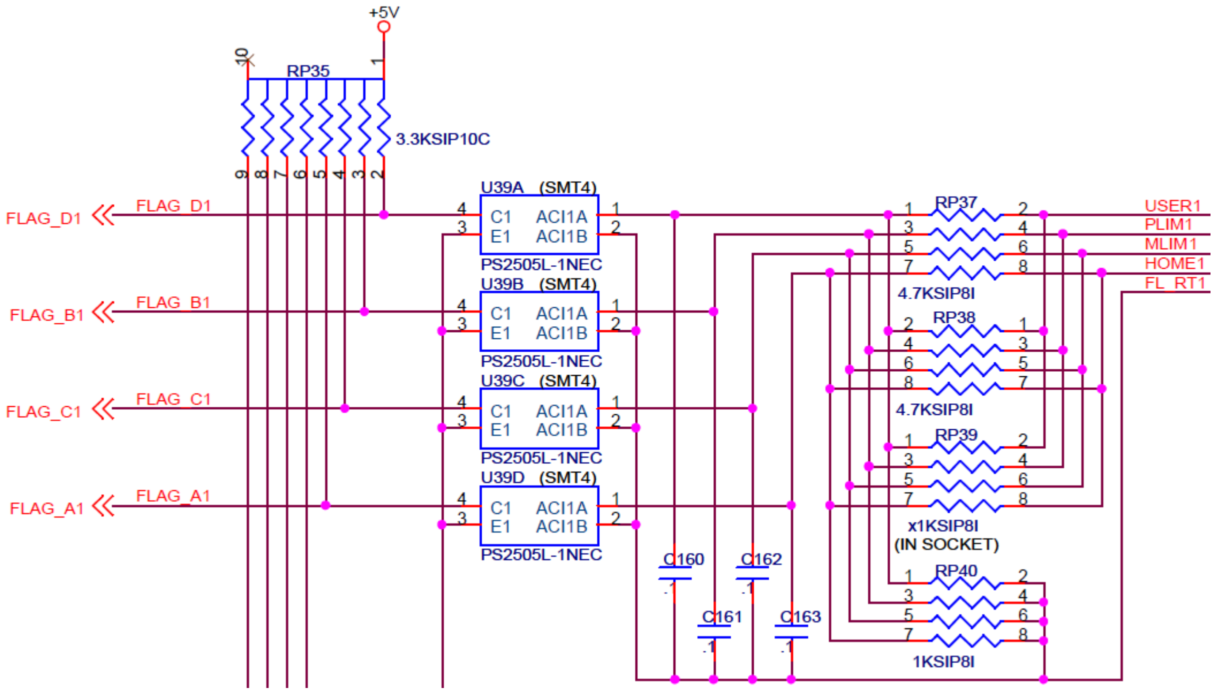
Inputs: J6 & J7



Outputs: J6 & J7



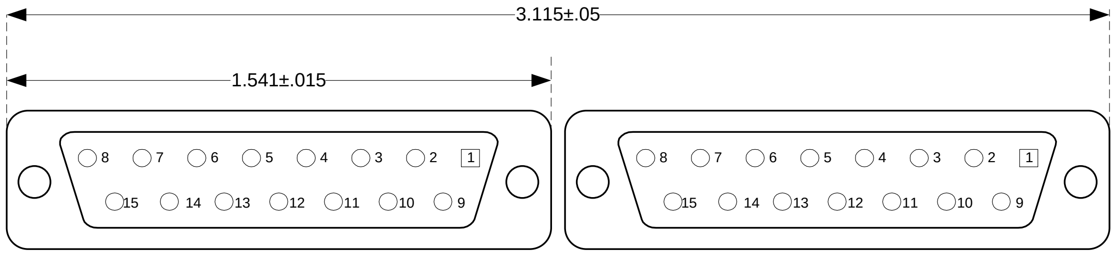
Limits & Flags: J4



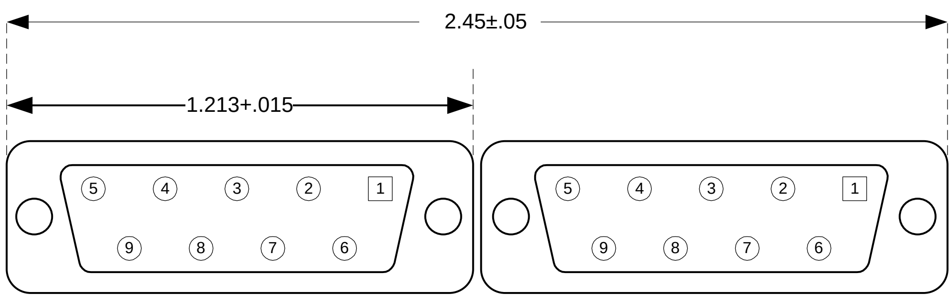
APPENDIX B

DB Connector Spacing Specifications

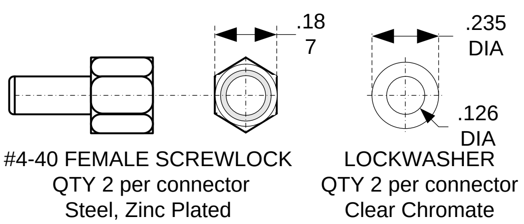
X1-8: DB-15 Connectors for encoder feedback



X9-12: DB-9 Connectors for Analog I/O



Screw Lock Size for all DB-connectors



Appendix C:

Control Board Jumpers (For Internal Use)

E6 – E9: AENA/GPIO Selection Jumper

E-Point	Description	Default
E6 1 2 3	Jump pins 1 to 2 for GPIO1 on X9 Jump Pins 2 to 3 for AENA5 on X9	See Part Number
E7 1 2 3	Jump pins 1 to 2 for GPIO2 on X10 Jump Pins 2 to 3 for AENA6 on X10	See Part Number
E8 1 2 3	Jump pins 1 to 2 for GPIO3 on X11 Jump Pins 2 to 3 for AENA3 on X11	See Part Number
E9 1 2 3	Jump pins 1 to 2 for GPIO4 on X12 Jump Pins 2 to 3 for AENA4 on X12	See Part Number

E10 – E12: Power-Up/Reset Load Source

E-Point	Description	Default
E10 1 2	E10 removed to load active memory from Flash IC on power-up	No Jumper
E11 1 2	Jump1-2 for normal mode operation	Installed
E12 1 2	Jump1-2 for normal mode operation	Installed

E13: Firmware Reload Enable (BOOT SW)

E-Point	Description	Default
E13 (1)(2)	Install E13 to reload firmware through the communications port. Remove jumper for normal operations.	No Jumper

E14: Watchdog Disable Jumper

E-Point	Description	Default
E14 (1)(2)	Jump 1 to 2 to disable Watchdog timer (for test purposes only, can be hazardous). Remove jumper to enable Watchdog timer.	No Jumper

E25-28: Select Encoder Index input or AENA output (channels 1-4)

E-Point	Description	Default
E25 (1)(2)	No Jumper for TTL Level input for Ch1 Index signal (C) Jumper 1-2 to output AENA1 at Ch1 encoder connector	No Jumper
E26 (1)(2)	No Jumper for TTL Level input for Ch2 Index signal (C) Jumper 1-2 to output AENA2 at Ch2 encoder connector	No Jumper
E27 (1)(2)	No Jumper for TTL Level input for Ch3 Index signal (C) Jumper 1-2 to output AENA3 at Ch3 encoder connector	No Jumper
E28 (1)(2)	No Jumper for TTL Level input for Ch4 Index signal (C) Jumper 1-2 to output AENA4 at Ch4 encoder connector	No Jumper

E35-38: Select Encoder Index input or AENA output (channels 5-8)

E-Point	Description	Default
E35 (1)(2)	No Jumper for TTL Level input for Ch5 Index signal (C) Jumper 1-2 to output AENA5 at Ch5 encoder connector	No Jumper
E36 (1)(2)	No Jumper for TTL Level input for Ch6 Index signal (C) Jumper 1-2 to output AENA6 at Ch6 encoder connector	No Jumper
E37 (1)(2)	No Jumper for TTL Level input for Ch7 Index signal (C) Jumper 1-2 to output AENA7 at Ch7 encoder connector	No Jumper
E38 (1)(2)	No Jumper for TTL Level input for Ch8 Index signal (C) Jumper 1-2 to output AENA8 at Ch8 encoder connector	No Jumper

E40: USB/Ethernet Communication Firmware Load Enable

E-Point	Description	Default
E40 (1)(2)	Remove Jumper to reload communication firmware	Installed

APPENDIX D

Absolute Serial Encoders Limitation With Turbo PMAC

The following is a summary of certain limitations which could be encountered with higher resolution absolute serial encoders, and a description of related registers with respect to the proposed setup techniques. Note that techniques 1 and 3 are processed in the Encoder Conversion Table (ECT) using the standard 5-bit shift, whereas technique 2 is processed with no shift.

Quick Comparison

Parameter/Description		Technique 1/3	Technique 2	Units
Resolution Scale Factor (SF)	Rotary	SF $=2^{ST}$	SF $=2^{ST-5}$	counts/revolution
	Linear	SF =1/RES	SF =1/(32*RES)	counts/user unit
Maximum open-loop velocity		2^{18}*ServoClk		counts/msec
Maximum closed-loop velocity		2^{23}*3/(Ixx08*32)		counts/msec
Maximum travel before rollover	Rotary	2^{47}/SF $=2^{47-ST}$	2^{47}/SF $=2^{47-(ST-5)}$	revolutions
	Linear	2^{47}/SF		user units

Where ST: is the rotary encoder Singleturn resolution in bits
RES: is the linear encoder resolution in user units (e.g. mm)
ServoClk: is the PMAC servo update rate in KHz
Ixx08: is Motor xx's position scale factor

Resolution Scale Factor (SF)

Turbo PMAC expects the motor count Least Significant Bit LSB to be left-shifted (5 bits), per techniques 1 or 3. The only difference then with technique 2, when unshifted, is that the motor position loop will now consider 1 LSB of the source to be 1/32 of a motor count, instead of 1.

Example: Take a 37-bit absolute serial rotary encoder (25-bit single turn, 12-bit multi-turn) and its equivalent linear scale (e.g.10 nm resolution):

Technique 1/3 (5-bit shift)	**Rotary**	2^{ST}	2^{25}= 33,554,432	**counts/revolution**
	Linear	1/RES	1/0.00001= 100,000	**counts/mm**
Technique 2 (no shift)	**Rotary**	2^{ST-5}	2^{20}= 1,048,576	**counts/revolution**
	Linear	1/(32*RES)	1/32*0.00001= 3,125	**counts/mm**

Note

Regardless of the processing technique, the servo algorithm utilizes "internally" the entire data bits stream (i.e. 25 bits) for its calculation. The performance is not compromised.

Maximum "Actual" Open-Loop Velocity

In open-loop mode, the actual velocity register is limited by the Encoder Conversion Table to 24 bits. Furthermore, it requires two samples (servo cycles) to compute the velocity. Therefore, the maximum value which the actual velocity register can withhold is:

$$\frac{2^{24-5^{\text{bit shift}}}}{2 \times Servo\ \text{Cycles[msec]}} = 2^{18} \times \text{Servo Clock[KHz]} \quad \text{counts/msec}$$

When performing an open-loop move/test with higher resolution serial encoders, care must be taken not to exceed this threshold. You will see saturation plateau lines in the position data if it is plotted during the move. At this point, re-establishing an absolute position read (using custom plc, or automatic settings) is necessary to avoid fatal following errors in closed loop and or to be able to perform proper motor phasing.

Example: Take a 37-bit absolute serial rotary encoder (25-bit single turn, 12-bit multi-turn) and its equivalent linear scale (e.g.10 nm resolution), and compare for two different clock settings:

With the default servo clock of **2.258 KHz**, the maximum actual open-loop velocity is MaxActVel=2^{18}*2.258= 591,921 [counts/msec] yielding:

	Rotary [rpm]	**Linear [mm/sec]**
	=MaxActVel*60000/SF	=MaxActVel*1000/SF
Technique 1/3 (5-bit shift)	1,058	5,919
Technique 2 (no shift)	33,870	189,414

With a servo clock setting of **4.500 KHz**, the maximum actual open-loop velocity is MaxActVel=2^{18}*4.500= 1,179,648 [counts/msec] yielding:

	Rotary [rpm]	**Linear [mm/sec]**
	=MaxActVel*60000/SF	=MaxActVel*1000/SF
Technique 1/3 (5-bit shift)	2,109	11,796
Technique 2 (no shift)	67,500	377,487

Note

The maximum actual velocity attainable is directly proportional to the servo clock frequency. The faster the servo update, the higher is the actual velocity threshold.

Maximum “Commanded” Closed-Loop Velocity

In closed-loop mode, the commanded (desired) velocity register is limited to:

$$\frac{2^{24-1\text{signbit}} \times 3}{\text{Ixx08} \times 32} = \frac{2^{18} \times 3}{\text{Ixx08}} \quad \text{counts/msec}$$

In terms of motor counts per millisecond, the maximum commanded velocity will be the same with or without shifting but since the number of counts per revolution “unshifted” is 32 times less, then the maximum programmable velocity is 32 times greater.

Example: Take a 37-bit absolute serial rotary encoder (25-bit Singleturn, 12-bit Multiturn) and its equivalent linear scale (e.g.10 nm resolution). The maximum ‘commanded” closed-loop velocity (Ixx16, Ixx22) setting programmable in Turbo PMAC is: 786,432 [counts/msec] with Ixx08=1
8,192 [counts/msec] with Ixx08=96

With Ixx08=1	**Rotary [rpm]**	**Linear [mm/sec]**
	=MaxCmdVel*60000/SF	=MaxCmdVel*1000/SF
Technique 1/3 (5-bit Shift)	1,406	7,864
Technique 2 (no Shift)	45,000	251,658

With Ixx08=96	**Rotary [rpm]**	**Linear [mm/sec]**
	=MaxCmdVel*60000/SF	=MaxCmdVel*1000/SF
Technique 1/3 (5-bit Shift)	14.645	81.916
Technique 2 (no Shift)	468.667	2621.334

Note

Notice the lower programmable closed-loop velocity settings with techniques 1 and 3 (5-bit shift), associated with the default position scale factor Ixx08 of 96.

Maximum Motor Travel

In Jog mode, the rollover is handled gracefully by PMAC and jogging can be virtually performed forever. However, this can be problematic when running a motion program indefinitely in incremental mode where the 48-bit fixed motor register can roll over much sooner than the 48-bit floating axis register.

Note

Absolute Serial Encoders with limited multi-turn range normally do roll over way before the motor position register in Turbo PMAC does (i.e. 12-bit multi-turn is 2048 revolutions in each direction)

Example: Take a 37-bit absolute serial rotary encoder (25-bit single turn, 12-bit multi-turn) and its equivalent linear scale (e.g.10 nm resolution):

		Total Travel Span	In each direction = Span/2	Units
Technique 1/3 (5-bit shift)	**Rotary**	2^{47-25}= 4,194,304	2,097,152	**revolutions**
	Linear	2^{47}/SF	1,407,374,883	**mm**
Technique 2 (no shift)	**Rotary**	2^{47-20}= 134,217,728	67,108,864	**revolutions**
	Linear	2^{47}/SF	45,035,996,274	**mm**